Hints to Power Users.

PLAIN, PRACTICAL POINTERS, FREE FROM HIGH SCIENCE, AND INTENDED FOR THE MAN WHO PAYS THE BILLS.

BY

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Dedication.

TO THE MEMORY OF

JAMES WATT

(1736–1819),

AND IN RECOGNITION OF WHAT HE DID
FOR POWER USERS.

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PREFACE.

Ours is pre-eminently the manufacturing nation, and knowledge of the proper and economical production and application of power is of vital importance to all. Yet in this important line there seem to be no sources of thorough every-day information, generally available by the ones most interested—those who pay the bills and who reap the benefits or suffer the losses consequent on good or bad construction and operation of the manufacturing plant.

The principal barrier between bill-paying power-users and a proper understanding of the principles governing the motive power of all classes of manufacture has been the highly technical character of the literature on the subject, not excepting even the special industrial periodicals, which are many and *excellent. The information therein contained* is

generally of a character entirely unfitted for the understanding of the "non-practical" man, as he is called, and couched in a style utterly unintelligible not only to the non-professional employer but to his most trusted lieutenants. To use a homely illustration, "The fodder is too high for the sheep."

It is in recognition of these patent facts that I have undertaken to give in plain, every-day English a series of memoranda, showing my readers not only the principal sources of loss, danger, and inconvenience in power-using, but the means of preventing the same.

These memoranda embrace hints and pointers (as to the power) concerning the entire establishment, from ash-pit to exhaust-head, and will point out the good and the bad features of which an expert's experience in applying power and in helping and advising power-users in a wide range of lines of manufacture, and over an extended field of observation and operation, enables me to judge.

These common-sense talks, embodying over twenty-five years' study and practical experience, should be found interesting and instructive to mill-owner, manturer, railroad magnate, steamboat manager, and,

in fact, to all those who have in any way to do with the generation, transmission and application of power.

I should be very glad to have power-users all over the country consult me in detail at any time as to designs and plans for new power-plants, or improvements in old ones.

ROBERT GRIMSHAW.

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HINTS TO POWER USERS.

True Source of Profit.

True profit in any business lies in reducing expenses rather than in increasing gross receipts. There are very few manufacturing establishments in which there are not important leaks, the stoppage of which would yield a profit without any other change being made in the management of the business. This is especially true in those establishments in which power is used, and more so, of course, in those in which the cost of power forms a considerable percentage of the total cost of production, than in those in which the power bears a small proportion to the other items of cost. This percentage generally reaches the highest in the case of manufacturers employing steam; and it is to such that I shall in great part address myself. I shall endeavor to give the result of my own and others' experience in generating, transmitting, and applying power, and to put what I shall have to say in "plain United States," so that the proprietor shall

be able to understand it as well as those do who are supposed to be "up" in engineering language and practice.

Various Sources of Loss.

Losses which occur in power-using may be divided into several classes, any one of which may take place with little or no influence by or upon those in any of the other classes. They may be in the generation of the power, in its transmission, or in its application. They may be connected with the boiler and its appurtenances; with the engine and its attachments; with water wheel, wind mill, or electric motor; with the shafting or other means of transmission. They may be caused by improper or insufficient appliances, by wrong setting thereof, or improper care and use.

Leaks of money are not so apparent as those of water or of steam. They may take place right under the nose of the proprietor, or even of the engineer, who may be letting value run away faster than by any material leak likely to take place.

Money may be wasted by paying either too much or too little in the purchase of the appliances. If there is waste in first cost it is irrevocable, appearing yearly under the various items of interest, depreciation, taxes, and insurance, and perhaps under that of repairs also. *It may even* affect the item of wages.

What Does Steam Do for Us?

There are few of us who reflect often enough, or sufficiently, as to just what steam does for us. We call this the age of steam and let it go at that; just as we call ourselves Christians, or Republicans, and all that, and never bother much about why, or to what extent we ought to devote a little time once in a great while, if not oftener, to thinking over just how useful steam is to us; how versatile; how strong; how willing; how unwearying.

It is our beast of burden. It takes ourselves and our goods upon its broad back and with the ponderous strength of the elephant and more than the speed of the race-horse, carries us or our property from Dan to Beersheba without losing breath or stumbling the while.

It is our draft animal. It draws cumbrous coaches, which are veritable palaces, upon highways which are smooth as the Neva's frozen flood. It draws behind it the population of a village, and the wealth of a province. It is our serf and slave, strong-armed and easily bidden, hewing down forests, moving huge trunks, sawing and planing them, with the furious, tireless energy of a madman, and the wondrous skill of the trained artisan.

It is our miller, making of the wheat and corn which it cuts and carries bread fit for a monarch's table. *It is our* weaver, spinning and weaving the

fabrics which we wear. It is our miner, bringing from the bowels of the earth their treasures, gems, fuels, and metals many, for our daily use, comfort, adornment.

It is our peace-maker ; bringing distant provinces near, and abolishing natural land-marks and divisions. It abridges distance, annihilates time.

But whether we style it our slave or our charger, our beast of burden or our gnome-like searcher for nature's valuables, we must treat him, her, or it properly. We must remember, in dealing with it, the motto, "*Suaviter in modo, fortiter in re.*"

If it breaks or tears, maims or kills, it is our own fault. We should curb it. Its temper is uncertain. It is liable at any time to assert itself; and if at such times it does not meet with prompt and effective opposition, the servant becomes the master and it rends and ruins.

What Should a Boiler Be?

In considering the points of a horse, any one who is well posted will tell you at once that he should have a wide forehead, fine muzzle, large nostrils, oblique shoulder blade, long and muscular fore-arm, broad nose, flat cannon-bones, deep chest, short back, etc., etc., etc. Every horse lover has the good points of a *horse* "*down* fine." Yet with such an important

matter as a boiler, who knows the desirable points or can repeat them off-hand ?

But the desiderata of a boiler have been or can be formulated, and it should be interesting to note what they are.

In the first place it should be safe. Then it should be simple; convenient to get at, around, and into; easy to handle and to repair ; compact ; quick to steam; constant in its circulation, and steady, too ; free from smoke ; able to work with any kind of water, good, bad, or indifferent ; a dry steamer ; and of course economical of fuel. In order to be all these things, the heating surface must be so arranged as to best take the heat from the gases of combustion and so as also to let the steam which is generated get away from those surfaces as rapidly as possible. It must be strong enough to stand any pressure that can be got up in it by fair means ; and should have a safety valve which will let off all the steam that can be generated in it, even if none is being drawn off. There must be no place where unequal expansion will make the boiler its own enemy. It must be saving of fuel not only at some one rate of steam production, but at the regular rated capacity ; and while it cannot be expected that a boiler will do as well with bad fuel, bad water, and bad firing as with all of these three good, it must be economical with all three bad.

Has your boiler all these points ?

"Danger Above."

Those of us who have watched the hoisting of a heavy safe or the demolition of a large building have sometimes been amused by the sign which is put upon the sidewalk to warn passers-by :

"DANGER ABOVE,"

for just what the danger can be anywhere except below has not yet been disclosed.

But the sign is often much more right than we have imagined. Just where it stands, it is often the fact that there is danger above. The danger is from the steam boiler underneath the sidewalk ; which threatens every one above it ; because such boilers are in places where they cannot be inspected properly or repaired rightly, and the amount of force which they have stored in them, and which is likely to be let loose in the twinkling of an eye, is almost incredible.

A common sixty-horse tubular boiler, full of steam and hot water at seventy-five pounds per square inch, stores 51,000,000 foot pounds of energy, of which but four per cent. is in the steam ; and this is enough to drive the boiler just about one mile into the air, with an initial velocity of nearly 600 feet per *second.*

Suppose that one of these were to let go just about the time when you passed over it ! The old lines of Casabianca,

> There came a burst of thunder sound ;
> The boy !—oh, where was he ?

might apply, with but sufficient variation to make the age—and perhaps the sex—right.

One of the cardinal principles of boiler-setting should be to have everything in sight, or plainly get-at-able ; so that if anything wrong occurs it shall be detected at once by inspection ; and if it takes place, it may be properly and promptly fixed.

But some cases have been put upon record where boilers underneath the sidewalk have been left with the safety valve fastened down by a piece of wood between the lever and the arch overhead ; others, where corrosions have been going on for months without being detected ; and in others again the gauge can hardly be seen with the aid of a torch.

Of course, in a great city like New York land i dear ; and sometimes it cannot be bought at any price and boilers must go under the sidewalk. In such cases there should be a law that there should be bright illumination not only attainable but kept up during all hours during which steam pressure is on, so that the danger from darkness may be lessened.

But this alone is not enough. There should be

laws preventing the use of the dangerous types of boilers which are so largely used ; boilers which, if an explosion takes place, will wreck the entire building under or near which they are placed. There are several kinds of steam generators, both patented and unpatented, in which if any part gives way all the damage that isdone to the boiler itself is merely local, while no harm can be done to the surroundings, the escape of steam from the ruptured surface being gradual and not violent.

A man has no more right to have a dangerous type of boiler under his sidewalk, or to keep a comparatively safe boiler in the dark, than he has to leave a loaded gun around where it is liable to be meddled with.

The law should take hold of this matter ; and those whose duty is to enforce the law should see that we are made safe.

Boiler Explosions.

Whenever a boiler "lets go of itself"—and this happens pretty often in these days of high pressure—we are interested for a while in the question of boiler explosions ; what they are and what causes them. Then we subside and wait until some particularly horrible case of loss of life and of damage to property *takes place,* when we open out our vials of wrath and

enroll our interest in the subject of safe boilers and safe methods of handling them.

There must be recognized a difference between explosion and mere bursting. The former implies that there is a report and very violent rupture of the boiler, while the latter may be merely a splitting or a cracking sufficient to let the steam escape gradually. The first works damage to the boiler itself, generally completely wrecking it. The second does not and may not put it out of service much longer than is required to cool it down and fire up again. (With some kinds of boiler—those which steam rapidly and early—this delay is particularly slight). Explosion is very apt to work damage to surrounding property; mere bursting or rupture without noise is not at all so.

There are a great many reasons why boilers explode, and they are quite well enough known. It is not, however, found that the knowledge thereof makes people any more careful of boilers put under their charge, nor much more fearful of those which are in positions where they are likely to work injury and destruction to life and property. It is said that "familiarity breeds contempt," and this is in a great measure true of steam. We know its great force and use it daily; we consider it as a giant who has immense strength and a very uncertain temper, but with whom the chances are that we shall not have

trouble right away. We intend, after we think that our good luck has nearly run out, to commence to take precautions, so that we shall not be caught napping. But we get caught at last; whether napping or not, it makes but little difference. If a man goes to sleep in this world and wakes up in the other, he is not much better off than if he is hurled from this one in a waking condition.

It might be about as well to name some of the causes why boilers explode and work damage.

Among them may be put, first, weakness of structure or design. That we should be able to control. We cannot make men careful, but we can, if they are making things which are known to be dangerous, prevent them from doing harm by that special form of design or method of construction which we know and have proved to be dangerous. That is, we can refuse to buy boilers which are dangerous, and we can also legislate so as to prevent others from risking our lives and property.

Safety valves stick. It is probable that they always will stick so long as their action depends upon the voluntary action of some one man or set of men. About the only thing that we can do (for we cannot legislate human nature out of existence) is to make things so that if the safety valve is even plugged up or fastened down the boiler cannot do anything more dangerous than just to split in some place or other

where there is not much steam or water, and after blowing off its excess, without wrecking anything, settle down for repairs.

Low water used to be considered about the only cause of boiler explosions, but its reputation in this particular seems to be very much too bad. Overheating the water, too sudden opening of the throttle-valves, or even the safety-valve, have been shown to produce explosion or rupture. As for this, about the only thing that we can do is to take the same precaution that we do about the safety-valve sticking—make the boiler so that, whatever happens, it cannot explode violently and generally, but will just split somewhere in a quiet, inoffensive, harmless way.

Of course decay comes in ; bad design and construction will hasten this.

The sudden throwing of feed water upon hot surfaces will cause bursting. We cannot insure that this shall not be done, but we can, as before said, make any bursting (other than a mere letting go in soı local spot) impossible.

There is no use in figuring up that there will only so much pressure of steam upon the boiler, because there is no knowing who is going to run it, nor what is going to happen to him, however competent ; so the boiler must be made with a great excess of strength in every part over any reasonable demands *likely to be* made upon it ; and then there must be

some part or parts the rupture of which would be little likely to do any damage and which will give way before any other and then act the part of safety-valve.

The boiler must not be so made as to have within itself unequal expansion strains, caused by some parts being heated much hotter than others and wrenching other parts asunder or damaging themselves. In other words, there must be as little as possible of this undesirable, unequal expansion, and what there is must be neutralized by a "take-up."

There should be plenty of metal, properly distributed ; the setting should be such as not to injure the boiler ; and there should be safety appliances which will prevent or neutralize, by rendering harmless, any ruptures which may occur.

There should be laws which will prevent any one selling a boiler which will explode as a whole. There is just as much reason for such laws as there is for preventing the storage of more than a limited amount of benzine or of gunpowder in a particular place. The principle is the same, that an explosive thing should be rendered as little explosive as possible, and that it should be handled by those skillful in its working.

Steady Steaming.

There are few things in which steadiness is not a *most desirable* quality. In an engine, regularity of

motion is for nearly every purpose an absolute requirement ; but what is a most amazing feature of modern engineering is that people who will haggle about the regulation of their engine, down to a quarter of a per cent. of a revolution, will make or put in boilers which are as spasmodic in their steam supply as an intermittent spring, and as violent and local in their circulation as a geyser.

Where a boiler will take almost any kind of water and about anything in the way of fuel, even permitting the fuel to be changed every few minutes—as in such places as umbrella-handle and cane manufactories, where they must burn the waste as fast as made,—when under these circumstances it will keep right on, hour after hour, furnishing just about the same amount and kind of steam,—that is a good boiler to tie to, in many respects. The boiler that blows for part of the time, and slows up the whole establishment at others, deranges the economy of nearly every concern in which it is placed ; while the one which will show no signs of distress if steam suddenly desired for such a "steam chewer" as power-hammer, is a good thing to have about.

Some boilers will be steady so long as they have steady, competent firemen, and then if they get a man who is not an expert will behave as badly as a spoiled child. As good firemen are very much more rare than poor ones, it is a bad feature in a boiler to have

to require a professor of chemistry and a meteorologist, an athlete and a diplomat, all rolled into one, to run it.

There is in some boilers a reservoir of heat which can be drawn upon to keep up steam when the combustion is low. In some the "brick arch" over the grate serves to gasefy the fuel just thrown in and to ignite the products of combustion at such a high temperature as to make their combustion more thorough and economical. In some the walls themselves have a mass of masonry which absorbs heat from the products of combustion as long as they are above a certain temperature and volume, and as soon as they cease to receive heat, at once give it out to the shell and its contents. Every boiler has its own peculiarities; and we must remember that a good one is that of steady steaming.

Compactness of Boilers.

There seem to be two classes of boilers; one in which the makers (or builders, for they seem much more like buildings than articles of manufacture) have tried to be as generous as their means will allow; and others where the aim and end being evidently to save space; everything else—especially accessibility—having been sacrificed.

But of the two the tendency seems to be more to-

ward compactness than toward mere bulk ; and of the two it is in most cases and for nearly every reason the more desirable of the extremes. It generally trenches on the accessibility of the boiler for inspection, cleaning, and repairing. It makes thin water spaces and hence promotes quick steaming ; but at the same time makes the boiler rather more "ticklish" about its feed. It offers in most cases rather more than the average facility for the deposit of mud and other impurities, while it also increases the difficulty of removing them.

Compactness is generally of greater value in cities than in the country. For instance, at the corner of Broad and Wall Streets, New York, the plot on which the Drexel building stands cost the present owners $1000 per square foot. Such space has a renting value, and there must be as little as possible of it taken up for things like boilers, which do not bring in rent. Money cannot be locked up just in space. And as it has been decided that the owner of a plot of land owns "heaven high and hell deep," boil which sacrifice vertical space for the purpose of s ing ground room, are becoming looked upon w special favor for city sites.

Compactness is for many reasons of more value aboard ship than on land, whether city or country. Space which is worth so much a cubic foot on land, *even on the* highest priced corner of the most expen-

sive street, would be reckoned cheap on the average ocean steamer, where the space accorded the coal and the crew, and everything that does not bring in so many dollars a trip, is looked upon as dead loss, and profit-robbing.

The Engineer in Chief of the Bureau of Steam Engineering of the United States Navy confided to me some years ago in defense of some very remarkably badly-proportioned engines and boilers, that his chief trial in life was to be handed the lines of a vessel after it had been arranged where the armor, and the guns, and the magazines, and all the rest of the warlike equipments of the ship were to go,—and then be told that he could put the engines and boilers where he could find a place for them.

In the country, where compact boilers are used, there is generally required a smaller and less expensive building, which of course costs less to put up and eats up less money in the shape of taxes, insurances, repairs, etc.

But, in aiming at compactness, it should be borne in mind that while this quality may be highly desirable and is so in most instances, accessibility is an absolute requirement.

"In shunning Scylla we must not rush into Charybdis."

Get-at-able Boilers.

It is a good maxim in any kind of construction that hidden work is apt to be, or to become bad. It may start out by being good, where the maker is competent and honest ; but sooner or later if you cannot get at it to inspect it, and repair it, there will be trouble. How few things give out when you can see where they are "going," ? Somewhere back or below or within, where the eye cannot reach or where light never penetrates, there is a leak or a crack or a spring or something wrong. A boiler, being an affair which may be highly dangerous, should be of a kind which will permit a man of moderate size not only to look it all over but to go all through it. His eyes should be able to rest upon every square inch of its heating surface ; and his hand should be able to feel every portion. If possible there should be room for a hammer to strike every part in order to determine by the ring which it gives or does not give, whether or not things are right. The boiler that you can get into, under and around, is, other things considered as equal, more desirable than one which cannot be got at. There is a great deal of human nature in mankind, and the average man is not going to break his back, and strain and twist his neck, and break his shins crawling under and over and by obstructions more or less sharp,

hard, and dirty. If he owns the boiler he will do all this perhaps under a sense of duty to himself; but remembering that after all the duty is principally due to himself he will postpone paying it until the last possible moment. Sometimes he postpones it until the last horn blows; and the last horn is an explosion.

Accessibility is a source of economy because the boiler that can be got at easily will be kept clean, and a clean boiler will make steam more cheaply than a dirty one.

The accessible boiler is more safe, other things being equal, than the one which cannot be got at without a great deal of trouble. Eternal vigilance is the price of safety no less than of liberty.

The boiler which can be got at will be less likely than any other to break down suddenly and stop a whole establishment; and, in these days, the stoppage of the steam supply may throw out of work hundreds and even thousands of hands; for steam is not only the source of power, it is the heating agent.

All things being considered, and considered in their true light and with their true weight, it pays in every way to provide in a boiler a fair degree of accessibility; and the boiler which is get-at-able is the one which can be trusted, day in and day out, to give better money's worth and cause less anxiety than the one which offers a premium on neglect.

Position of Heating Surface.

Once in a while the papers publish recipes for making this, that, or the other article of food, in which the proportions of all the ingredients but one are given with a degree of nicety that would do credit to a chemist's laboratory ; but the amount required of that one is given as "some." In straining at a gnat of nicety, with respect to some of the elements, the author of the recipe swallows a camel of carelessness or inexactness concerning the other.

It is so in many engineering matters. For instance, people are very careful to state the exact proportion that should exist between the grate surface and the heating surface, but they say nothing and seem to care for nothing about the position of that heating surface ; and position has as much to do with steaming as mere area has.

It is not merely enough that a lathe tool shall have a certain size and angle of point ; the point must be presented to the work at the proper angle. The sam way with heating surface. If presented at one ang to the action of the flame or heated gases of con bustion it will have one value ; and if presented a some other angle its value will be entirely different.

This being the case, it is well to look into the matter and see what angles are the best for the heating surface *to have, in order* to have the greatest value.

The two extremes are vertical and horizontal; between which, of course, there is any number of grades of inclination.

The relative values due to different positions of heating surface has been determined by direct experiments with the following approximate results:

One square foot of heating surface placed at right angles to the current of heated gases so as to receive them by direct impact, was found to equal four square feet when placed diagonally to the current, or eight square feet when placed in a direction parallel to their flow. This shows the importance of securing a direct impact of heated gases against the absorbing surfaces of the boiler, whenever the designs can favor it. In all ordinary boiler construction this matter is wholly overlooked or disregarded, more attention having been paid to it in the designing of sectional boilers than, perhaps, any other class.

In some boilers this matter receives full and proper attention, and, what is of equal if not greater importance, the surfaces are so arranged as to permit disengagement of the steam when generated by contact against the hot walls of the tubes, the intention being to have a maximum amount of steam generated and to have it liberated with the least possible unnecessary disturbance,—to have steady currents rather than intermittent explosions.

In view of this fact, it is well in buying boilers as

well as in designing them, to see that they have heating surface in good position ; and if the design of the boiler is such as not to permit this, to see that there is more than enough of this badly placed heating surface to counteract, if possible, the evil effect of bad position.

Choice of Boiler Material.

In buying a boiler you have your choice, as to material, among cast iron, wrought iron, and steel, and each of these has its advantages, according to the conditions. Wrought iron is most used, although steel plates are rapidly coming into use, too. Whichever one of these two is used, it should be bought of a firm of acknowledged reputation, and should bear upon every sheet the name or trade mark of the firm, and the tensile strength per square inch which it is guaranteed to stand. This should be not less than 45,000 pounds per square inch.

Plain Horizontal Cylinder Boiler.

This is the most simple kind made,—just a plain wrought-iron or steel horizontal cylinder, having either flat or convex ends (preferably the latter). They often receive the furnace or other heat only in *their lower surfaces*, although a development of this

is to run the gases of combustion from front to back underneath, then from back to front along one side, then from front to back along the other side to the stack or the flue. They should have manholes in the head or end, not in the cylindrically convex shell. The lowest water level should come above the top of the side flues or passages.

Plain Vertical Cylinder Boiler.

Where, as in iron works, there are great quantities of hot waste gases, these are often applied to the generation of steam in long vertical cylinders, set in a masonry stack, between which and the boiler shell the hot gases pass. The upper portion, above the water level, should be fenced off with a fire-brick ring, so that no hot gases shall touch any metal that does not have water on the other side of it—an imperative and very good rule to apply to all boilers.

Both this type and the plain horizontal cylinder are simple in the extreme, and while not compact or light for a given capacity, and not very economical in fuel, are well adapted to very rough usage.

Flue Boilers.

Slightly more complicated and expensive than the *plain cylinder* types, are what are known as "flue

boilers," in which there are large flues, from two to six in number, traversing the entire length of the shell, below the water line. The gases of combustion pass under the shell and return through these flues, which of course are surrounded and touched by water on all sides. They answer quite well where fuel economy is not so much an object as exemption from leakage and repairs, but are, of course, somewhat less desirable in this particular and in the matter of first cost than the plain horizontal cylinders. Gain in fuel economy is accompanied by increased first cost, and trouble from and expense of repairs. The power user may make his choice to suit his own case.

Internally Fired Boilers.

A class of generator very largely used across the Atlantic, and in one form commencing to be used here, consists of a large horizontal cylinder, having below the water level one or two large, lengthwise flues, in one end of which the grates are placed. The gases of combustion pass back through these tube (which are entirely surrounded and touched b water), and then pass frontward, below the water line, and sometimes entirely under the shell to a flue leading to the stack. Properly designed and built, these boilers are reasonably economical of fuel, and give *but little trouble* as regards repairs; while in com-

pactness they occupy a place midway between the flue boiler and the return tube cylinder type, which next claims our attention.

Return Tube Cylinder Boiler.*

Among the various classes of wrought iron or steel boilers, the most common in this country is probably the plain, externally fired, cylindrical return tube type, in which the flames, after passing back under the boiler, pass through small tubes lengthwise of the main shell, under the water line.

This is a much more compact boiler, power for power, than the types just described ; and while more expensive, is yet of considerable simplicity ; for while it has many more parts, seams, and joints than the others, they are all plain shapes, easy to make and join.

It is not adapted to districts where the water contains large quantities of impurities, as, while the ashes, etc., in the tubes themselves are easily cleaned out by brush scraper, or steam jet, the spaces among them are difficult of access and hard to get clean.

This type should have its lengthwise seams out of

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* For about 800 practical questions and answers concerning care and use of all kinds of boilers, consult my Steam Boiler Catechism, price $2.00 ; to be had of the Practical Publishing *Co., 21 Park Row*, N. Y.

reach of the flames and double riveted. There should be no dome, but in its place there should be a dry-pipe, made by cutting a number of slots in a long length of pipe of the same diameter as that which carries the steam away from the boiler, and which latter pipe should communicate with the center of this dry-pipe, and with no other portion of the boiler. The ends of this pipe should be closed, so that all the steam which leaves the boiler should have to pass through the fine slots, thus straining out the water which would otherwise be likely to be carried over with it, causing loss of fuel and injuring the cylinder heads of the engine. The shell should have plenty of facilities for inspection in the way of manholes and hand-holes. The manhole should not ordinarily be in the convex part of the shell, for the same reason that there should not be any dome, that the large opening necessary weakens the shell.

Gaskets.

It is important that the joints of all manholes and handholes be well packed to prevent the escape of steam or water. For this purpose if ordinary rubber gaskets be used, they should be rubbed on both sides with chalk or black lead to prevent their sticking and thus getting torn.

Gaskets of corrugated sheet copper last much longer than rubber, especially if the joints are to be broken

often; but are of course much more expensive. They will stand a higher steam pressure and temperature without being spoiled ; in fact they are the only kind that can be used to advantage with superheated steam.

Punching.

Where riveted holes are punched it is well that they be done with a punch which will not strain the sheet, and which will also enable the work to be done equally and with little expenditure of power. This is accomplished by having the cutting face of the punch spiral, so as to commence its cut at one side of the circle and work around like a pair of shears.

Steel boilers should have their rivet holes drilled instead of punched ; but if punching is resorted to, the sheets should be annealed after punching, as this tends to counteract the injurious action of the punch on the metal immediately around the hole.

Riveting.

Rivets should be fastened up by power, particularly where they are long in proportion to their diameter and where holes are punched with considerable "flare." A power-fastened rivet fills the hole much more thoroughly than one headed by hand ; and *makes a joint* which is not only tighter but stronger.

Calking.

The seams of wrought iron or steel boilers should be calked with a round-nosed tool, in order to prevent the plate under the seams from being scored by the sharp edge of the upper plate.

Welded Seams.

It is perhaps best not have any lengthwise seams at all. This can be accomplished by having them welded by great hydraulic pressure, and will probably soon be done by electricity.

Tube Expanders.

The tubes should be made to hold well and be tight in the heads by the use of a roller expander, and every fireman should have one of these, so that at the first sign of a leak at the tube ends he can remedy the trouble. A competent fireman, on the lookout for his employer's interest, will keep all tubes tight if you give him the facilities, and proper appreciation and recognition of his forethought.

Sectional Generators.

In order to increase the heating surface as compared with the quantity of water contained in the boiler,

and also, by lessening the size of parts liable to rupture, to diminish both their likelihood of bursting and the damage which would be caused by such an accident, there are made what are known as "sectional" boilers, which have another feature which often proves valuable—ability to be carried into mountainous districts, where parts weighing over four hundred pounds would be difficult and expensive, if not almost impossible to transport. In these the heating surfaces are largely composed of wrought-iron tubes or of cast iron spheres, containing the water to be heated, and among which the gases of combustion pass on their road from the combustion chamber to the stack.

The number of sectional boilers is legion. Some are good, some bad, some very bad. There are a few which have been doing good service, year in and year out, for long terms of years, and which of course can be bought without any risk of trouble by their exploding, leaking all the time, or wasting coal. The makers of some of them have got their business down to a very fine point, and can deliver what is wanted and give a definite guarantee, which they are able to back up in case of need.

But even if you have a sectional safety boiler, see to it that it is treated just as though it was liable to explode any minute. Even although your building is fireproof you do not court fire risks ; then, even if *your boiler is* supposed to be proof against explosion,

do not offer a premium upon accidents. Bear in mind that every boiler is always just going to explode ; act as though you were afraid of it, and you will not be apt to have any trouble with it on that score. Always have on hand "spares" of the extra parts of your sectional boiler, so that in case of one part giving way it may be replaced in the least possible time.

Dome.

Do not order a dome on any new boiler. There are very few cases where the addition of one to an old shell will increase its steaming capacity or make it produce drier steam to such an extent as to warrant your ordering it ; and in most cases it seriously weakens the shell. The dry pipe and the dome do very well what the dome does only partially. If you want to consider it as a reservoir for steam, just figure out how many—or how few—cylinderfuls of steam it will hold. If there is a dome on a boiler which you buy, see to it that the shell is reinforced by a flanged wrought iron or mild steel ring where the hole for the dome is cut out, and where the ring of holes for the dome rivets extend.

Mud Drum.

A mud drum is at best a mere antidote. Best not let *the mud get* into your boiler ; then you will not

need a place for it to settle in. If you do have one, see that it is out of the way of the flames, so that the mud will not get baked on it. Never order one drum for two boilers. If you already have such a bad arrangement see that there is a place at which to blow it out, and a handhole (or better yet a manhole) to permit of inspection and cleaning.

Instead of a mud drum, use a feed water filter.

Glass Water Gauge.

There should be attached, preferably to the head of the boiler, a glass water gauge, by which the level of the water may be ascertained at a glance.

It is absolutely essential that there shall be some method of seeing where the water is without going over to the boiler for that purpose. A properly constructed glass water gauge apparatus, with Scotch glass, will, if it be properly proportioned and attached, show the same water level in the tube as there is in the boiler. There should, of course, be provision for clearing out the steam passages with a steel rod when they get wholly or partially filled up with scale or sediment ; and it is well to have them with a safety attachment, so that in case of breakage of the glass the steam and water shall be shut off so as to save the engineer from a scalding and permit the insertion of

a new glass. Always have extra glasses at hand. When one is wanted it is needed right away.

Try Cocks.

There should be also three or more try cocks, placed diagonally one above another. These are very well to supplement the water gauge glass, and in fact I would rather have them alone than the glass alone. Whatever kind are used, they should be put at proper levels so as to indicate when the water gets anywhere near the danger level. The fireman should be instructed to try each one at least three times a day. It takes but little time for one to get clogged, under certain conditions—and but little time, also, for the water level to get run down to the danger limit, under favorable circumstances.

Safety Valves.

Once the boiler is made and set, all possible precautions should be taken to insure perfect immunity from explosion. The first thing requisite is a safety valv of the most approved pattern, and this should b tested daily by raising it to let the steam blow. See t it that your fireman is able to calculate (1) the weight requisite to close the valve where the steam pressure *and the length* of the lever are given; (2) the distance

at which a given weight should be hung, when the pressure is given ; and (3) the pressure at which the valve will blow, where the weight of the "pee" and the distance from the fulcrum, are given.

In some States the local ordinances call for two valves on each boiler ; each able to discharge all the steam it can make. The United States laws provide for one square inch of valve area for two square feet of grate for ordinary valves, and one square inch for four square feet where the lift will give an effective area of one half that due to the diameter. No valve should be over four inches in diameter. Flat valves are less likely to stick fast than those having conical disks. Where there are two valves they may be combined in one casing so that there need be but one hole to cut in the shell, and but one joint to make and to keep tight.

One very nice arrangement is to have the stop valve and the safety valve combined.

Dial Pressure Gauge.

Next to the safety valve the most important thing upon a boiler is the pressure gauge. This should be put upon the top of the dome, drum, or boiler, and should be tested every three months to see that its spring has not got set. It should be attached by means of a coil of one turn of pipe to catch condensed

water and to prevent live steam getting at the spring and "setting" it. (This does not apply to mercury gauges.)

The records of local boiler inspectors and of the boiler insurance companies show that a very large proportion of the pressure gauges, on the accuracy of which so many lives and so much property depend, are incorrect. The expression, "To lie like a gas meter," should be changed to, "To lie like a pressure gauge." It is strange how people will be so cautious in business matters, and so little observant and disposed to test things in matters such as these.

Recording Gauge.

It is highly desirable that the regular pressure gauge be supplemented, by a recording gauge.

There are few better investments that can be made about a power plant of any size, than a well-constructed and accurate instrument of this class. It will check and regulate unfaithfulness and incompetence on the part of the fireman, and of course be to a considerable extent a protector from danger by explosion. It will not, certainly, make men competent, nor make them honest and faithful ; but it will enable you to detect incompetence and unfaithfulness and remedy either or both by getting a new man when the *old one is* not up to the standard.

Low Water Alarm.

The recording gauge should be really an electric low water alarm ; but there are some which have steam whistles attached to them which do good service. (It is well to consider, in this connection, the danger of alarming a mill full of employees by the shrill scream of a low water alarm whistle.)

Damper Regulator.

There are several kinds of these : some act by the expansion of air, some by the pressure of steam ; all have for their object closing the damper in the stack when the pressure gets to a certain point. The way to find out whether the one which is offered to you for sale is good or not, in your particular case, is like the rule for seeing whether a match is or is not good ; try it. Put one on, connect it with the damper, fire up all you can, with the stop valve shut, and if the regulator permits the pressure to get above that fixed as the maximum, consider that it is no good. If it lets the pressure get below a certain point, that may or may not be the fault of the regulator ; it may be the boiler's fault—a regulator is never claimed to *make* steam ; but if it fails to prevent the pressure rising, even with the stop valve shut off, don't bother *with it.* There are few cases where the damper regu-

lator should not speedily control the steam. Of course if the boiler is set in a great mass of masonry, which has been let get red hot, and the water level is low, and the mass of coals well glowing, the regulator may not keep down the pressure, and you may have to depend on the safety valves. Valves, I say, for I assume that on every boiler there will be two, law or no law.

Muffler.

It is well to have on the safety valve discharge pipe a muffler which will prevent the roar of escaping steam from annoying or alarming any one. In some places there is so much noise when the valves open to lift, that you can hardly hear yourself think ; and in others a sudden escape of steam in large quantities might cause a panic.

Whistle.

If there is a whistle upon the boiler it should not be of the shrill kind which tends to make life hideous, but a chime, sounding two or more notes in harmony.

Reducing Valve.

If there are two or more boilers connected together, and one of them is allowed to carry more pressure than *the other*, or if a high-pressure boiler is intended

to supply a range of low-pressure pipes for heating, etc., it is desirable to have a reliable reducing valve, by which there may be absolutely no danger of the maximum pressure at which it is set being exceeded. A reducing valve is particularly desirable at the inlet of a steam heating system taking steam at a pressure greater than the fixtures will stand without leaking.

The Grate.

It is impossible to have economy in fuel if there is a wasteful grate. It is necessary to have one which shall let a large quantity of air through it without letting any fuel drop through. This grate must also be of such a design as to be quickly and easily replaceable in case of accident to any part of it, but it must not be of a kind that will warp or crack from the heat of the furnace.

There are in the market many different kinds of patent grates; some of them of no use whatever, others well worth the money asked for them. No grate should be put in which has not at least fifty per cent. of air space between the bars; and it is best not to try experiments. As a general thing let some one else do the experimenting. Put in grates which you know to be doing good service and which those who use them recommend; remembering, of course, that *the best* recommendation is a second order, by a well-

posted person, who has no personal interest in the device, nor friendship for the inventor or salesman.

Shaking grates have the merit of permitting the fire to be cleaned often, evenly all over, and only a little at a time, instead of being coaled up in great quantity and raked out wholesale. Besides this the fire is not chilled by frequent opening of the door in cleaning.

Spare grates or sections should always be on hand, so that in case of the failure of one, a new one may be dropped into place in short order.

One word right here. There is no grate which can burn economically more fuel than a certain maximum well known to competent professional engineers. A grate merely holds the coal for the draft to burn. If the boiler furnace has too little draft, no mere arrangement of cast iron bars between or around air spaces will burn the fuel.

Separator.

A separator or so-called steam drier, whether pat ented or home-made, is at best but a remedy, although one often needed. If you find that you are stuck with a boiler which makes wet steam, or that the one which you have must be forced so as to give wet steam, it is well to try a dry pipe, perforated with *fine holes or* saw kerfs, and extending along the in-

side of the boiler in the steam room. This is an appliance long and favorably known, although not so often applied as it should be. If such a dry pipe will not do, then try a separator. There are two or three in the market ; other things being equal, buy the one which is spoken of the best by those competent to judge, and not interested in it or its manufacturer or salesman.

You must not, however, expect every separator or other steam skimming appliance to do more than remedy in part the evil caused by unduly forcing the boiler, or by permitting local currents in the circulation, which tend to fill the ready-made steam with spume.

Boiler Covering.

No matter how cheap your fuel is, have your boiler covered with a non-conducting covering. If it is in the open air or in an exposed place the covering will save its cost, many times over, in fuel ; and if it is in a close room, it will not only save fuel but render the fireman's life more endurable. Consult the comfort of your men, in this, as in other things. If you don't care anything for their health and comfort, they will care little for your safety and nothing for your profit and loss account. The saw-mill owner who has to hire a man to burn his excess of sawdust in a *cremating furnace*, may question the necessity of using a

boiler-covering—but he should remember that every unnecessary pound of fuel which is consumed on his grates lessens the life of his grates, boiler, and stack.

Of all the boiler coverings in the market those are the best, other things being equal, which contain the most air. Plain old fashioned hair felt is good where the pressures (which affect temperatures) are not high ; or where the temperature is high, whether the pressure is or not. Get one which is either readily removable for inspection of the boiler, or easily repaired in case it must be taken off in places. No matter what covering you use on boiler or pipes, be sure that it is white on the outside, as, other things being equal, white radiates less heat from a given area than any other color.

Various Steam Pipe and Boiler Coverings.

The substances employed in non-conducting coverings for steam pipes and boilers are legion ; yet there are half a dozen or so which are common to nearly all of them.

It is demanded of such coverings that they shall non-conducting, heat-resisting, tenacious or n(cracking, non-corrosive, adherent to hot iron, lit affected by leakage, low in radiating power, easy o- first application (and sometimes of taking off and replacing), and capable of taking a neat finish.

Sometimes it is desirable that they be self-binding or formed into a solid mass that will hold itself together. To this there may be added lightness in weight, and cheapness of first cost and of application.

There is no one substance which has in any great degree all the properties named. It may be interesting to classify the materials used, alone or in combination ; naming each material and stating its qualities, and stating each quality and naming the materials which possess it.

Among non-conductors when used alone may be classed wood strips, hair, wool, hair felt, wool felt, cork, infusorial earth, mineral wool, rock wool, pumice stone, sawdust, charcoal, paper pulp, plaster of paris, ashes, and air spaces.

As heat resistants we may mention asbestos, plaster of paris, uncalcined gypsum, sand, clay, ashes, charcoal, soapstone, pumice stone, chalk, infusorial earth, mineral wool, rock wool.

Among binding materials to resist tendency to crack, there are hair, wool, woody fiber, paper pulp, asbestos fiber, and, perhaps, sawdust. Canvas, wire gauze, and either black or tinned iron jackets are used to hold pulverulent materials.

As adherent to hot iron, clay seems the most satisfactory.

Of those little affected, as regards their durability,

by leakage, there are wood strips, cork, felt, air spaces, hydraulic cement, plaster of paris cement, silicate of soda, asbestos, sand, sawdust, charcoal, pumice stone, soapstone. Of these, air space and plaster of paris have their heat conducting power but very little increased by water logging ; the reverse is the case with the rest.

As regards radiating power, as light colors, smooth surfaces, and metallic luster serve to diminish radiation, we find plaster of paris, lime, and tinned iron jackets for air spaces desirable factors.

Ease of first application depends on situation and other circumstances. Where the pipes are very hot, sectional coverings come in handy. Where a plaster covering is used, clay seems to do better than other matrices.

In ease of removal and re-application, we have wooden strips, cork strips, and sheets bound on with wire ; loosely woven asbestos cloth; sectional plates and tubes ; metal jackets having non-conducting air space under them.

For neatness of finish the wood strips, the metal and canvas jackets, and many of the plastic compounds, commend themselves.

Lightness of weight is found in wood strips, sawdust, cork, hair, wool, hair felt, wool felt, paper pulp, charcoal, pumice stone, mineral wool, rock wool, etc.

As regards cost, none of these substances are very expensive, except the felts, and perhaps some of the wire gauzes.

In the following table I give, opposite the names of each material, crosses in the column headed with properties which their materials possess :

	Non-conductivity.	Resistance to Heat.	Tenacity.	Non-corroding.	Adherence to Hot Iron.	Resistance to Leakage.	Low Radiating Power.	Ease of First Application.	Ease of Replacement.	Finish.	Lightness in Weight.	Cheapness.
Asbestos cloth......................		X	X	X		X	X	X	X			
Asbestos in plaster compounds......		X		X			X	X		X		
Wood strips or lagging	X		X	X		X		X	X	X		X
Hair felt..........................	X		X	X		X		X	X		X	
Wool felt..........................	X		X	X		X		X	X		X	
Dark metal jackets and air space....		X	X	X		X			X	X	X	
Bright " " " "	X	X	X	X		X	X		X	X	X	
Cork fragments in white jacket.....	X		X	X		X	X		X	X	X	
Cork strips and sheets in plaster....	X			X			X	X		X	X	
Infusorial earth in a white jacket...	X	X	X	X			X			X	X	X
" " " plastic compound	X	X		X			X	X		X	X	X
Plaster of paris in plastic compound		X					X	X		X	X	X
Raw plaster........................							X	X		X		X
Sand...............................		X		X					X			X
Rock wool in jackets...............	X	X	X	X		X	X		X	X		
" " " plastic compound......				X			X	X		X		X
Mineral wool in jackets............	X	X	X			X	X		X	X	X	
" " " plastic compound. .							X	X		X		X
Pumice stone.......................	X	X		X		X		X			X	
Sawdust............................	X			X		X		X			X	X
Charcoal..............	X			X		X		X			X	
Paper pulp (white)	X			X			X	X		X	X	
Ashes (mineral coal)...............		X						X				X

Feed-Water Filter.

No matter what way you choose to feed the water into the boiler, it is important that it be pure: if it contain mineral substance, any solution or other matters in suspension, these will be deposited upon the surface of the sheet and tubes and cause a scale which will prevent the heat of the furnace or of the gases of combustion from going into the water to make steam, while at the same time the boiler is in danger of being burned. So that the deposit of scale is not only a waste of fuel, but a source of danger from explosion. These substances should be filtered out, so that the water may be practically pure.

There are many filters on the market; some of them mere strainers, and others regular dummies, passing the water and doing it no good. A filter which does not get foul and require to be cleaned out, is doing no good as a filter.

Feed-Water Heater.

As every particle of heat which the furnace has to put into the water in order to make it into steam costs money in the shape of coal, it is desirable that the feed water be as hot as it can be made. For this reason there should be between the pump or injector and the boiler a feed heater, which will put the water

into the boiler as near 212 degrees as possible; this heater raising the temperature of the feed water by utilizing the heat of the exhaust steam of the engine, or of the gases of combustion after they have passed through the boiler.

There is another advantage in having feed water heated, particularly if the feed is not constant. The hot sheet tubes of the boiler are chilled by having cold water thrown upon them. This has the double effect of causing cracking and lowering the steam pressure. We may safely say that no manufacturer who has any idea of safety or of economy will feed cold water into his boiler.

The most common impurities in hard water are salts of lime, of magnesia, and of iron ; the most frequently found of these being carbonates.

Where the steam pressure is 60 pounds there is 12 per cent. saving by heating the feed from 50 degrees to 200 degrees. With this as a basis, any one can cipher this up for himself. If his coal bill is $200 per week he will save $24 a week by heating his feed water from 50 to 200 degrees, supposing that he is running with 60 pounds pressure. Besides this there are indirect savings by reason of increasing the life of the boiler, etc.

The test of efficiency of a combined feed water filter and heater is not merely a change in color and temperature of the water which has passed through it.

Water which comes through perfectly transparent may contain a marked percentage of chemically-dissolved impurities, which will be deposited on the shell and tubes of the boiler if heated above 250 degrees or even above 212 degrees. To test whether or not your combined heater and filter is efficient, weigh an ounce of the feed water before pumping ; evaporate it to dryness in a test tube and weigh what is left ; then similarly evaporate an ounce of water which has been heated and filtered, and see how much less solid is left. If there is just as much in the second instance as in the first, the apparatus is worthless as a filter. If there was considerable before heating and filtering, and none after, the appliance is doing good service. If there is little or no solid substance in the water no filter is needed.

The Feed Pump.*

The manner in which the feed water is supplied to the boiler is most important, as also is its temperature and purity. As regards the manner of feeding, that may be by either a pump or an injector, and if by a pump it may be driven by belt from the shafting of

* Several hundred practical questions concerning pumps of all kinds are answered in my Pump Catechism, two volumes in one, price $2.00 ; to be had of the Practical Publishing Co., 21 Park Row, N. Y. In it are given full instructions how to set up, adjust, and run nearly every pump on the market.

the establishment, or it may be self-contained. The first is called a power pump and the second a steam pump. Power pumps may be either belted or geared. Steam pumps may be positive driven, or direct acting, neither of these names conveying its proper meaning. The advantage of having steam pumps instead of those driven by belt is seen in time of fire in the establishment. If there is anything the matter with the belt, or the engine is not going, the pump cannot be run, but a steam pump is independent of outside matters and runs upon its own merits.

The feed should be regular and constant; the water should not be pumped up spasmodically from time to time. If the demand for steam varies, of course the amount pumped may be increased or diminished, but there should always be feed going into the boiler, as long as there is steam going out of it. The pump should have capacity to deliver four times as much water as the boiler can evaporate.

The feed pump should be so connected as to be usable for fire extinguishment also, if necessary ; and sometimes it will be found desirable to have connections by which it can fill the water tank on the roof.

Where a boiler is fed only from the street mains under pressure,—without the use of a pump or an injector, as sometimes happens where there is very considerable pressure on the mains,—there should be *provision for* feed in case of stoppage of the water-

works engines or of any trouble with the mains. It is all well enough to let the water-works fill your boilers week in and week out ; but you should be ready to take care of yourself in case of an emergency. The pump valves should be readily accessible for inspection and removal.

The Check Valve.

There should be attached to the feed pump, in addito its own discharge valve and the shut-off valve, and coming between these two, an efficient check valve, which will permit the water to pass into the boiler, but not allow any to pass out ; otherwise there might be trouble by scalding water blowing through and causing risk by letting the water in the boiler run out, even if no one were scalded. The check valve enables the pump to be disconnected without using the stop valve, and permits the stop valve to be packed or repaired without the necessity of drawing the fires.

Injectors.

Instead of pumps, injectors are now used by many, and they have the advantage of being very simple and compact. While many of them are simple and *just as effective* as the pumps, their operation is a

paradox, as a jet of steam from the boiler is made to strike a current of water and feed it into the boiler against the pressure of that steam itself.

The same rule which applies to constant feed with pumps, holds good where injectors are used ; there should always be a stream of water going into the boiler, so long as there is a current of steam going out of it.

The injector, like the pump, should be able to supply, when in good working order, four times as much water as the boiler can evaporate when doing its best. Then there should be little or no trouble with low water by reason of defective feed. There should be both a check valve and a stop valve ; the latter between the check valve and the injector.

Steam Augers.

The "steam auger" is an iron pipe with a special nozzle on one end and supplied with steam through a flexible hose. Its purpose is to blow through the flues of tubular boilers, and remove the soot, ashes etc., which stick to their sides. See to it that your fireman is furnished with one and made to use it. The softer the fuel you burn, and the more wood—particularly soft pine—you use, the oftener you should *use the steam* flue-cleaner. A boiler which permits

the flames and hot gases to radiate heat to flues which are clean will steam more rapidly and economically than if the heating surface has a non-conducting covering of fine ashes.

Boiler Setting.

Having got the boiler, it is important that it be set properly, for fifty per cent. of the power that a boiler will give off may be lost by bad setting, and, outside of this, bad brick setting will not last half so long as that which is properly done. Fire-bricks should be used for the bridge wall and for the inside lining of the main walls. The walls should be set upon stone foundations so that they will not crack by settling, as cracks not only lead to the destruction of the walls, but cause leakages of air into the furnace. If you will look into your boiler furnace, you will probably see, if the setting is bad, blue flames at the cracks in the side walls. They are caused by the air which leaks in combining with the carbonic oxide gas, which is a product of incomplete combustion.

Do not expect too much of a boiler. You cannot get out of it any more than the law allows—the law which says that there is only so much heating power in a ton of coal, and that a pound of coal cannot make more than a certain number of pounds of steam at a *stated pressure* out of water at a stated temperature.

Leaks.

Never let a steam leak keep up longer than is absolutely necessary. Of course you can't shut down a mill for the purpose of stopping a petty leak ; but the first chance that you have, see to it that each leak which is observed, be it little or big, is stopped absolutely ; not lessened, but stopped. Every sizzle and drip about the place tells of your ignorance or carelessness. It is a great pity that steam is not gold-colored, so that when it leaks or is blown off through the safety valve it might remind you how your profits were being distributed over the face of the earth. Outside of the direct loss caused by leaks, they occasion indirect losses by acting as general demoralizers of the entire establishment.

Steam Traps.

Every range of steam pipes should be provided with a trap to collect the water of condensation and return it to the boiler or to some point whence it may be pumped back. This water, if allowed to get into the cylinder of the engine, would endanger it ; it is also, if not returned to the boiler, a source of loss.

"Boiler Horse Power."

This is a much abused term. In old times, when it took a cubic foot of water, evaporated into low pressure steam, to produce a horse power in a primitive engine, a "hundred horse power" boiler was one which would serve a hundred horse power engine, and the rule of a cubic foot of water per hour per horse power (the temperature of the water, when fed in, or the pressure of the steam, being ignored as unimportant) was considered good enough. Now, however, a boiler maker may sell one boiler to a man who has direct acting steam pumps that take 80 pounds of steam per hour per horse power; another just like it to serve a slide valve engine taking 40 pounds, and a third exactly similar to supply a compound condensing engine, which will produce a horse power for every 20 pounds of steam per hour supplied to it. If each of these boilers evaporated 2000 pounds per hour, the first would be a 25 horse boiler, the second a 50, and the third a 100; while a fourth, used for heating only, would be of no actual horse power at all.

In order to make some conventional standard which can be understood, even if not expressed, professional engineers have united in assuming one boiler horse power as the evaporation of 30 pounds of water per hour from 70° Fahrenheit into steam at 100 pounds *pressure per* square inch; on which basis, the genera-

tor which made steam at 100 pounds pressure out of 2000 pounds per hour of water at 70° F. would be a 66⅔ horse boiler, and this being now "the usage of the trade," the courts would so decide it, in the absence of any different agreement.

Too Much Power.

One of the most common faults is buying a boiler or an engine much too large for the work that it has to do, at the time of purchase, or in the near future. The engine is more often bought too large for the boiler than the reverse. One cause of loss under this head is buying an automatic cut-off engine where a plain slide valve would answer; this is particularly the case with small powers. Another is buying a condensing engine where the load is very light or the steam pressure very high, or both. The purchase of an engine much too large for the boiler makes it necessary to run at too low steam pressure, or to cut off too early in the stroke. I should here say that up to a limit of about two hundred pounds per square inch, there is a saving in using high pressure steam, provided, of course, that it is properly used. Improperly used—that is, in too large an engine or at too slow or too fast piston speed, the saving caused by having high pressure steam may be neutralized by the other conditions being wrong. High pressure necessitates using

high grade boilers, made of the very best tested and guaranteed materials, in the very best way, and of a design which shall be safe from danger to life or property, economical in the generation of steam, and durable ; saving in the items of depreciation and repairs. Where possible, compactness is desirable ; but it is not paramount.

Whatever boiler you buy, see to it that you get a moderate reserve of power. If your plant is very large there will generally be economy in having several comparatively small boilers instead of a few large ones, as they accommodate themselves more readily to changes from day to day in the amount of steam required. It is generally good policy to get a little extra strength, so that if at any time you find it desirable to increase the pressure for the purpose of getting more out of the engine, you can do it—always, of course, providing that the engine can stand it ; a fact which should be arranged for with its builder.

Emergencies.

If you take steam from a steam supply company will be well to have a boiler at hand ready to suppl at least a part of the steam needed, in case of accident to the mains, or dispute about the rates. There is so much human nature in mankind that you will be *likely to find* the connections with your establishment

kept in better condition, and the bills more carefully laid out, if you are able to "paddle your own canoe" at a moment's notice. Of course, if you are running a daily newspaper you will have to be ready to supply your own steam on the very shortest notice, company or no company.

Never under any circumstances have two boilers so connected together that you cannot use either one of them alone, while the other is being inspected or repaired, or is desired out of service. There are many establishments—and this is particularly true of flouring mills—where it is found highly advantageous to make of the whole plant two distinct sections, each complete and independent, so that it is perfectly feasible to run on half production with maximum economy and minimum trouble. In the case of daily newspapers and of steamboats, division of the power generating appliances into two is especially desirable, as half speed may be attained without risk of any kind, which is not the case where a single engine or boiler is started up after temporary repairs.

Stack.

Have stack enough for your boiler to give you good draught under all circumstances of wind and weather. *If there is too* much you can shut it off. See to it

that the temperature of the escaping gases at the top of the stack is low ; that they are not hot enough to burn a shingle ; not even hot enough to set fire to paper. If you are sending out of your chimney top gases hot enough to fire paper and even wood, you are not getting out of the fuel anywhere near as much as it is possible for you to do. See to it, in fact, that the gases as they leave the boiler and enter the stack, are at a comparatively low temperature. There is no money in heating up a stack for the four winds of heaven to cool off. What you burn coal for is to turn water into steam.

Whatever kind of a chimney you have, see that it is smooth inside. The rougher it is inside the less the draught will be. A round section costs rather more to build, but is a trifle the better shape.

In building your chimney, don't forget to leave a door at its base by which it may be entered ; nor to leave climbing irons by which it may be ascended for inspection or repairs. It sometimes costs a cool $100 for "Steeple Jack" to get to the top of a stack from which the climbing irons have been forgotten.

It is well to attach a lightning rod, if care is taken to make connections at the ground end, with the street system of gas pipes or water pipes, or to have a good large "earth plate" buried in a wet stratum.

The Fireman.

You may pay any price asked for "black diamonds"; may have the best boiler in seven counties, and a stack that will draw fire out of slate ; but if the fireman doesn't know his business you can't expect economical steam-making. One man will throw in coal half a wheelbarrow full at a time ; another will send it in with a small shovel, little and often. One will have a fire fifteen inches thick ; another will have his grate covered with the same coal, only about four inches. One will have a great heap in the center of the grate and the corners bare ; the other will have the layer over every square inch of the grate, and thickest all around the edges so as to be saucer-shaped. One will keep the hand of the gauge dancing and jumping, and the damper flopping first one way and then the other ; the other will see that the index of the gauge goes where he wants it and stays there as long as he wishes it to.

The first man will be a muscular fireman, able to toss any amount of coal (at your expense) through the furnace door ; the other will be a brainy fireman, interested in sparing himself hard manual labor, and in saving you money.

If you have a fireman who cannot do any better than to let the steam get low one hour and blow off the next, discharge him ; he would be dear at ten

cents a week. Whatever fireman you do engage, let him understand that after the first week the pointer is to be kept at a certain degree on the gauge ; and that when it points to any other place it will point to his discharge. Let him understand thoroughly just what the special demands are for steam ; just about how great and when he may expect them. After a week he should be able to keep things going smoothly and not have the power hammers or the dye tubs wait for steam one hour and the safety valves blowing off the next. Damper regulator or no damper regulator, the fireman should either keep steam steady or quit.

Ventilating Fan or Ejector.

An employer never loses anything by making his men comfortable. There are cases where the boiler room sets low, and the building is surrounded by others which prevent ventilation, where it will be advisable to have a ventilating fan or an ejector, to draw out the hot air or to throw in cold, as the case may be. In most cases, however, ventilating apparatus will suffice ; and it must be remembered that too much ventilation must be paid for in the coal bill The *juste milieu* is not difficult to attain.

Fuels.

There is very seldom any choice left to the power user whether he will use coal, coke, or wood. He generally starts out with the idea that one of these is cheaper than the others, and prepares for that. But in the matter of burning screenings and shavings, lignite, sawdust, oil, or natural gas, he generally has a choice. Sometimes he doesn't make a wise one. This is a matter which should be well studied out. As between good coal and good wood, a ton of the former is worth about two cords of the latter. The other fuels are generally supplied at rates which vary greatly according to purely commercial circumstances.

If you want to decide as to which of two fuels is the more economical, provide for each the grate which is best adapted for it; then arrange for the same boiler, or for two exactly similar boilers, to be used in the test; get the conditions exactly the same and make a run of not less than ten hours with each (a week's run is better than a day's). The question of quickness with which the fire can be got up, and of speed with which it will run down, should be considered, as also the important one of liability to excessive local heating of the plates—a common trouble with shavings and similar fuel.

Coals.

Among coals, there is twenty per cent. difference to be found in those on the market in the same bin. Some have more slate or dirt than others, and some, outside of the slate which they hold and which can be readily seen, have much more ash. If the coal which will evaporate eight pounds of water per pound of coal costs $5 per ton, and one which will evaporate only seven pounds, under the same conditions, costs $4.75, the $5 coal can be seen to be much the cheaper, without going into the question, which will come up in larger establishments, of the decreased number of men required to stoke, and the lower cost of getting rid of the ashes.

Coal should be kept dry and under cover, as it loses its heating properties by exposure ; and soft coal is liable to spontaneous combustion. In buying coal see that it has not been "stored" in the open air, particularly in the wet season.

Screenings and Slack.

Screenings and slack require a special grate ; and their price is generally adjusted pretty closely to their actual value. There is usually a slight economy in using them if the plant is near to where large shipments of coal cause great accumulations of slack.

Sawdust.

Sawdust is extremely difficult to burn. If you have it on hand in large quantities and must get rid of it, it will sometimes pay better to burn it under the boiler than to go to the expense of cremation furnaces to burn it up. The trouble is that in most places where there are large quantities of sawdust, there is also a plenty of slabs and other refuse of which it is just as important to get rid as the sawdust. In places where the sawdust is a minor product, and the insurance companies require that it be got rid of quickly, it is well to burn nothing but it during certain hours of the day, and to rely upon the regular fuel the rest of the time. In such cases, all the sawdust that is burned causes a direct saving of coal.

Lignite.

Lignite is generally burned in districts where it is plenty and coal is scarce. It takes plenty of air space in the grate, and special handling in firing. The question as to which to burn, lignite or coal, seldom comes up.

Oil.

Oil can be burned perfectly well under steam boilers. It is a mistaken idea that the world is wait-

ing for a perfect oil burner. There are plenty of them which do excellently well. The only trouble is purely commercial. It takes a certain quantity of oil to equal a ton of coal. If that oil costs more than the coal it will not pay to burn it, and that is all there is to it. The Standard Oil Company burns oil under some of its boilers at times ; those times being when it cannot get therefor a price as great as the coal which it displaces would cost.

Oil has the great merit of being very readily controlled ; you can force the steam fiercely or reduce it to a minimum, in very short order. You can keep the steam production at a given rate all day without touching the adjustment.

Gas.

Gas shares with oil the very desirable feature of high controllability. Whether it shall be burned or not is generally a purely commercial problem which can only be solved on the spot. One man finds that it will pay him to substitute gas for coal, and his neighbor right opposite him finds that it doesn't. There is one way to find out : try it. When the price of the one which you are burning gets higher than that of enough of the other one to do the same work, change.

When an agent comes around and talks about sav-

ing fifty to seventy-five per cent. of your fuel bills by some attachment or other, politely show him the door. If he talks only five to ten per cent., listen to him.

Kinds of Engines.

Of the various kinds of stationary steam engines used to generate power, we may make several classifications. First of all we may divide them into rotary, in which the piston rotates about its own axis and that of its cylinder or case ; and reciprocating, in which the piston travels to and fro lengthwise of its cylinder.

Rotary Engines.

These are seldom used except where directly coupled to a pump, fan, blower, or other rapidly running machine. They have the advantages of being simple and easy running, besides which they save the expense of shafting, belting, etc., where they are directly attached to the machine to be driven ; but as they are not economical of fuel, they are but little used as motors (in the strict sense of the word) for large powers. They are difficult to pack and to keep tight.

Reciprocating Engines.

Nearly all the steam engines used are in this type; but there are many classes and sub-classes. For instance, they may be single acting, in which the steam acts on only one side of the piston; or double acting, in which it acts on both sides. They may be single cylinder, in which there is but one cylinder working upon the shaft; or duplex, if there are two of exactly the same kind and duty. They may be compound, in case the exhaust from one cylinder goes into one or more cylinders, there to do additional duty; or non-compound, if the exhaust does not so perform a second duty. If their exhaust is condensed by cold water, they are "condensing"; otherwise they are non-condensing. They may or may not use steam expansively, although a non-expansive engine, used as a motor, independent of a pump directly attached thereto, is a rarity. If they do "cut off" the steam so as to use it expansively, this cut off may be either fixed or variable (also called adjustable); and in the latter case the adjustment or variation may be effectable while the engine is running, or only after stopping it. If this adjustment of the cut off to suit the load is effected by the engine itself, through its regulator or governor, the engine is said to be "automatic"; as are also, really, engines in which the governor regulates the initial steam pressure instead

of the point in the stroke at which it is cut off; although in this case the name "automatic" is usually denied them, and they are called "throttling" engines.

There is a further classification into horizontal, vertical, and inclined, according to the position of the cross-head guides, where there are any. If the crank is above the cylinder the engine is "inverted vertical."

The cylinder may be fixed on a bed or frame, or it may swing on trunnions, in which case the engine is said to be oscillating. (This type is rare on land, and becoming scarce afloat.)

Where the piston consists, instead of a head and rod acting on a connecting rod or directly upon a plunger or a piston, of a "trunk" or hollow cylinder in which vibrates a connecting rod, attached directly to the piston, the construction is known as a trunk engine; but this type is rare on shore; as also is that kind in which the trunk passes through a stuffing box so that steam may be used upon the full area of the piston on one side and upon a smaller area upon the other (half trunk type).

When the connecting rod of a horizontal reciprocating engine on the out stroke passes under the line of the main shaft, the engine is said to be "under running"; if on the out stroke it passes over the line of the main shaft it is "over running."

Where the connecting rod of an inverted vertical

engine drives the crank through the intermediation of a horizontal beam, vibrating in a vertical plane, and of another connecting rod, the engine is of the "beam" class; but the great "Centennial" Corliss engine is about the only example of this class that most persons have seen for driving factory machinery.

A very important element of classification is the steam distribution. The valves which effect this may be slides, plugs, or poppets; and slides may be subdivided into flat, piston, or cylindrical slides, and rock valves.

The plain or flat slide may be unbalanced, in which case the steam in the steam chest, by pressing against its whole upper surface (by which is understood the surface opposite to that which works against the valve seat), forces it against its seat, causing considerable friction—or it may be balanced, in which case a large portion of its upper surface is relieved from unbalanced pressure.

The cut-off mechanism may be either positive, in which case the governor never loses its connection with the valve, or "drop" cut off, in which case the governor delivers control of the cut-off mechanism to a weight or a spring, which effects the actual closure at that point in the stroke indicated and permitted by the governor.

We have here a host of differences; or rather a *host of lines* on which differences may exist; and the

same engine may be in a dozen different classes at once; thus it may be an inverted, vertical, double-acting, oscillating, balanced slide-valve, automatic, detached cut-off, non-compound, condensing trunk engine.

Each distinctive feature has some reason for its existence, is valuable in certain conditions, and may be detrimental in others. The intending purchaser should first acquaint himself with all the conditions under which the engine which he intends to buy is to operate, and should then check off the effect of each of these conditions on the various features of each engine among those from which the selection is to be made.

After stating the desirable features which an engine should if possible possess, I shall rehearse the advantages and disadvantages of each of the principal types.

What Should an Engine Be?

There are many good qualities which an engine may have, and most of which are compatible with the others, although some of them are impossible to realize in a high degree together.

Among these desirable qualities may be mentioned strength, durability, compactness, lightness, steadiness of running under varying pressures and loads; ease of transportation, setting up, adjustment, inspec-

tion, and repair ; difficulty of being tampered with by malicious persons or injured by incompetent ones ; ability to run at high speed with but little foundation, and to maintain cool bearings when running rapidly under heavy load ; low first cost ; economy of fuel and oil, and possibility of being regularly run by a person of comparatively low grade of intelligence, experience, and skill.

No one engine can have all of these qualities. Which of them has each of the various classes which we have named ? and what conditions call for each of these qualities ?

Throttling Engines.

These have the governor acting directly on a throttle valve, so as to choke the steam down before stroke end, when the load is light, and let it retain nearly the initial pressure when the load is heavy. The cut off is fixed and late in the stroke, so that the advantage of expansive action it practically dispensed with. Such engines usually, however, govern quite well, and are characterized by simplicity in design and construction; while for power under twenty-five—and many think forty—horse power, they can be used to advantage where automatic cut-off engines would, by reason of excessive cost, be out of the question. They are *usually durable* by reason of their great simplicity ;

compact; easy to set up, adjust, inspect, run, and repair; not readily tampered with or easily injured through ignorance; are cheap to start with; and almost anybody can run them somehow.

Automatic Cut-off Engines.

In most cases, for powers of over twenty-five horse, these are a necessity; at any rate where the machinery requires close regulation, and fuel is high. They are not usually constructed to stand much abuse; few of them are as compact as throttling engines; they require greater skill in setting up, adjustment, and repair; and many of them may be readily injured through malice or ignorance. They should be put in the hands of good engine-runners, who should be made to understand that they are expected to produce and maintain steadily good results as regards steam economy, steadiness of running, and exemption from repairs.

Horizontal Engines.

These constitute the most usual type of stationary engines. They generally require expensive foundations, which add greatly to the first cost of the plant; *are not* compact, when compared with the vertical *type; are* usually convenient to get at. From the

nature of the reversals of direction which occur at the end of each single stroke, they are not adapted to high speeds in upper stories, but are usually installed at the lowest possible convenient point. In the very largest sizes they may give trouble from the cylinder wearing out of round and the piston rod getting out of center.

Vertical Engines.

These are usually made in either very small or very large sizes, the vertical cylinder being chosen for small powers because the horizontal plan would call for too much floor space for a given amount of power; while very large engines are given vertical cylinders because the expense of foundations for horizontal engines of equal capacity would be too great, and the room taken up excessive. They keep their cylinder bores in good shape, and retain the centrality of the piston rod in the stuffing box longer than horizontal ones of the same size and piston speed. Wear of the main bearings often tends to derange the steam distribution by drawing the valves downward.

Plain Slide-Valve Engines.

There are more engines with plain slide valves than *with any other class.* These valves are cheap, simple,

durable, fairly efficient as steam disributors, easy to comprehend, adjust, and repair, and permit of the most simple methods of actuating them, of varying the grade of cut off, and of reversing the engine; are particularly out of the way of malicious mischief and of accidental injury.

Rock Valves.

These valves have all the defects of plain, flat slide valves, in distribution, without the advantages which the latter have in the way of ease of adjustment and repair. A slide valve is easily scraped, filed, or planed off if it gets out of level; so is its seat; and the two newly trued surfaces, when put together, fit as perfectly as before. With the rock valve, however, wear of either the valve or the seat makes a difference between the diameters of the circles which should fit together, and steam leakage is the necessary consequence. The rock valve has, however, this advantage, that it is easy to balance.

Piston Valves.

The piston valve is coming into favor from its cheapness and the ease with which it is balanced. It has the same defect which the rock valve has, that the

valve and its seat wear to different circles; but a plain piston valve is cheaper and easier to replace, when worn, than a rock valve, and the steam distribution is not changed by boring out the seat and inserting a new and larger valve, as happens with the rocking type.

Plug Valves.

The power user who is considering the question of buying an engine with plug valves—that is, one in which the valves are nearly cylindrical in outline and partially rotate on their axes—must remember the first thing, that it is to a plug-valve engine—that of George H. Corliss—that we owe the first really economical use of steam by a high pressure, non-compound non-condensing engine ; and that plug-valve engines stand confessedly in the front rank as coal savers and steady runners. The plug principle enables the valves to be placed at the very ends of the cylinders, thus saving in waste clearance space ; and also readily permits the exhaust to be given a separate valve for its release at times, independent of the questions o admission or cut off. These advantages it shares witl other classes of valves ; but nearly all plug-valve engines have them in high degree. The axis of the valve being at right angles to that of the cylinder permits the use of a most delicate valve-operating

mechanism; while the valve friction is but slight, and a large area may be quickly opened for steam inlet or discharge, and as quickly closed for cut off, by a very trifling and easily regulatable movement. The principle trouble with most plug valves lies in their wearing to a different diameter of cross section than the seats which they originally fit steam tight; and excessive and irregular wear of the valve stems.

Poppet Valves.

The poppet or beat valve has been highly successful for marine practice, where large engines are the rule. It has the advantage of giving immense steam area with but trifling valve motion; a lift of one fourth the effective valve diameter giving an open annular area equal to that of the whole circular opening beneath; thus a valve eight inches in diameter need be lifted but two inches to give it full discharge. Proper attention to details of construction will obviate the slamming which is sometimes noticed with the best poppet valves.

So far, however, the poppet valve engine is not a very important competitor for mill-driving purposes, particularly in small sizes. Most of those which are in the field are excellent engines; in fact the poppet *principle* practically precludes poor design or faulty *construction.*

What is a Horse Power?

This is a question which is asked over and over again, and which seems never to get answered permanently, nor to have its answer so plainly stated as to be absolutely unmisunderstandable. There is but one unit in British and American practice ; the equivalent of 33,000 pounds lifted one foot high in a minute. Not merely 33,000 pounds lifted one foot high, or its equivalent ; but the work must be performed in a minute. It takes no more power to lift 33,000 pounds one foot high in half a minute, than to lift it in one minute ; but it takes double the *horse* power. A horse power represents not merely work, but work done in a certain time. A one-horse-power engine can raise 33,000,000 pounds a foot high in a thousand minutes, or 33,000 pounds a thousand feet high in the same time ; but to raise 33,000,000 pounds a foot high in one minute, or 33,000 pounds a thousand feet high in the same time, would require one thousand horse power.

The size of an engine has not all to do with its horse power. Its speed, the boiler pressure, and the point of cut off, have just as much to do with it. Thus an engine of 18 inches bore, with thirty pounds mean effective pressure (not boiler pressure) per square

inch,* will develop 100 horse power at a piston speed of 432 feet per minute, which would be 108 turns per minute of a 24-inch stroke engine. With only 15 pounds mean effective pressure, and 108 turns, the same engine would give but 50 horse power; with 30 pounds mean effective pressure and 54 turns, only 50 horse power. Now if the mean effective pressure for a given point of cut off was 30 pounds, with 60 pounds by the gauge boiler pressure, it would be only 15 pounds with 22½ pounds by the gauge; and there would be 45 pounds mean effective pressure with a boiler showing 97½ pounds by the gauge. So the engine which would be a 50 horse with 22½ pounds boiler pressure would be 100 horse with 60 pounds, and 150 horse with 97½ pounds. The horse powers are not directly as the boiler pressures shown by the gauge, but are practically as the actual boiler pressures above vacuum; the pressures above vacuum being found by adding 14.7 (or practically 15) to those shown by the gauge. Thus 100 pounds by the gauge gives only about 1¾ times the mean effective pressure (and consequently the horse power) which can be had

* How to calculate the mean effective pressure, as well as over 800 other practical matters concerning steam engines of all kinds, is answered in my Steam Engine Catechism, two volumes in one, price $2.00. How to set up, adjust, and run all the principal engines in the market, is told in great detail in my *Engine Runners' Catechism*, price $2.00. Both are to be had of the *Practical Publishing* Co., 21 Park Row, N. Y.

from 50 pounds by the gauge; for 115÷65= only 1.77. The horse powers are directly as the mean effective pressures, directly as the piston areas, and directly as the piston speeds. They are as the squares of the piston diameters; that is, a 36-inch cylinder gives four times the horse power (other things besides piston diameter being equal) of an 18-inch. Mean effective pressures are not directly as the points of cut off ; thus, cutting off at one-half stroke may with one boiler pressure give one and three quarter times the mean effective pressure got by cutting off at one quarter, while with another boiler pressure it may give only one and one half times as much.

I have gone much further into the technicalities of the steam engine than I would have done were it not absolutely necessary to show the engine-buyer who is not "up" in the mathematics of the steam engine (1) that an engine horse power is a definite quantity involving time as much as mere push, pull, or lift ; and (2) that the term "100 horse-power engine" is so loose as to be a dangerous one to use.

The moral is that in buying an engine to give a certain horse power, the purchaser should stipulate that it should give that many horse power at a given number of turns per minute, with a stated initial cylinder pressure, and with a specified point of cut off—which point should be about five-eighths stroke of an ordinary *slide-valve* engine, and from one fifth to one

third—say one fourth—of an automatic cut-off engine of any of the higher grades. The stipulation should also be made that this should also be done "non-condensing;" that is, without the aid of a condenser, and with ordinarily dry steam. The contract or order should also state very definitely that the horse power shall be "net"—that is, deliverable by the engine to run machinery, and exclusive of the power required to overcome the friction of the engine itself.

As regards the so-called horse power of a boiler, I have expressed my views quite plainly and decidedly under the heading "Boiler Horse Power," page 65; while at the same time I have defined the now legal conventional standard.

Engine Speed.

This is one of the most mooted points in modern engineering. It did not come up in the time of Watt, nor indeed for nearly a hundred years after his early engine-building days; the great revolution in engine design and construction wrought by Sickles and Corliss tending to keep speeds slow by reason of the drop cut-off feature. But the introduction of positive governing engines, and the bold—in fact what then seemed rash and audacious—attempts of Porter and others to reach out into piston speeds expressed by *four figures*, brought with it a new and important

question for discussion ; two, in fact ; that of piston speed, and that of rotation speed or number of turns per minute.

The advocates of slow piston speeds based their arguments principally on constructive lines, alleging that high speeds called either for excessive cylinder length, which increased the cost and size of the engine, or for frequent reversals, which necessitated multiplication of shocks due to piston reversals.

Those enrolled under the banner of high piston speeds showed the theoretical advantages of using the steam before it had time to be chilled by the cylinder walls, and proved beyond question that steam could enter a port and traverse a passage at rates previously supposed impossible. They met the charges of heating the engine and racking it to pieces, by building engines which kept cool and ran quietly, under most exacting conditions, to the utmost satisfaction of all concerned, and won a substantial victory by first compelling all makers of positive cut-off engines to speed up, and then driving the builders of detached cut-off both to piston speeds and to rotation speeds which they had all along been declaring—and believing—impossible.

The low-speed builders then relied upon superior regulation—as against which the high-speed makers urged the necessity for expensive shafting and belting, *to bring the* rotation speed up to that requisite for

most machinery ; meanwhile, being driven to improving regulation, as the low-speed builders had been forced to raising their piston speed and rotation speed. And so, like leapers in a contest, each has in turn set the goal further and further ahead—to the great advantage of purchasers, who have been given better engines each year, and have been better protected than they otherwise would be by the guarantees which rival builders have been both willing and able to give.

At last, after both sides acquitting themselves with glory, each has been brought to acknowledge, even if reluctantly, what the engine buyer has in the mean time seen plainly, that neither one should be carried to extremes, and that neither is adapted for all places alike,—that the ponderous, slow-moving engine is the best for heavy machinery running at slow rotation speeds and giving very sudden fluctuations of loads ; that lighter, slow-moving engines, with a fineness of regulation almost marvelous, will best drive textile machinery, paper machinery, and other loads where the load variations are not excessive, but where speed variations would occasion injury to the product ; that such loads as printing presses do well with quite high speeds and good or even fairly decent governing, and that certain classes of electric light machinery call for engines having the highest piston and rotation speeds, and a ticklishness of regulation which would *be useless* almost anywhere else.

Choosing an Engine.

It is hard to advise any one about buying an engine without knowing all the conditions. One rule may be set down as a safe one,—not to buy new types as yet untried. As I said before, in another connection, let some one else than yourself do the experimenting. This may seem hard on the inventor, but in these "hints" I am looking out for the interests of the power user. There may be cases where a well-known builder starts out with a new type, to which he has been giving a great deal of time and attention, and which he will guarantee to do certain things better than those which he has been building; but as a general rule, an engine which has not been on the market for a couple of years is a good one to let alone. One thing sure, you are always safe in *not* buying it.

As between a "plain slide-valve" and an "automatic cut-off," there is now seldom any question for most situations. Under forty horse there may be many cases where it will pay to get a plain slide; very few above that, where it is not best to buy an automatic cut-off,—or at least an adjustable cut-off. There is to be considered, not only the fuel, but the matter of regulation; and even if fuel costs nothing, the engine which consumes the most steam requires the largest boiler, and boilers are not free in any part of the country that I have got into yet. Where good

mechanics and engineers cannot be got at, as in mining districts, the more simple the engine the better, as a general thing.

In buying an engine always see to it that you have enough cylinder thickness to permit at least two reborings; that it is strong enough to stand a higher pressure than you at first give it; and that it has bearings large enough to permit of higher speed than you at first get out of it. The time may come when the extra pressure or increased speed, or both, will be much needed; then there will be no trouble at all to give the engine more pressure, and very little trouble or expense to alter the pulleys for higher engine speed.

The remarks which were made on page 95 as regards duplication of the engine, or having a pair of engines to do the work, so that one may be used in case the other is injured or not needed, should be borne in mind here; and this is particularly the case where great loss or panic would be likely to result in case the entire engine power was shut down. Crippling a daily newspaper by reason of the only engine giving out, is a very serious matter, involving not only the direct loss caused by losing the sales of an edition, but indirect damage due to popular irritation against a paper which slips an issue, no matter from what cause. The stoppage of an electric light plant which supplied a church or a theater might be the direct cause of a

panic which might prove one of the greatest of calamities.

Two Engines or One?

Under the head of Emergencies, page 67, I discuss the question of so connecting two boilers that either of them may be put out of service without the other being withdrawn ; and I incidentally refer to the advantages of having more than one boiler. Just now I have two aspects of the "two engines or one" question : one as regards the mere method of connection ; the other, and much the more important, that of economy and convenience.

Two engines generally cost more than one having the same power as the two combined. In very large sizes the necessity of making special drawings, specifications, and patterns for a single engine larger than is usually called for, may run the first cost of one large engine higher than that of two having together the same power ; and the extra expense of foundation and erection for the "mammoth" may still further increase the difference in favor of the two instead of one. But taking it by and large, the customer may as well make up his mind that it will cost him more in first cost and in maintenance for two engines than for one. As against that, there is the advantage *which increases* with the number of operatives which

would be thrown out of work by the stoppage of the machinery, and with the net profit of the establishment--of being able to run at least half the machinery, or all at half speed, if only one engine be withdrawn by accident or for repairs. In fact, many types of engine are capable of having their capacity doubled from that power at which they show maximum economy. Being made to do double the work, the steam economy may be greatly reduced ; but this may be a very small item compared with loss of wages, where these have to be paid whether the machinery runs or not ; or with loss of profits when wages stop with the machinery. Failure to get a certain job done by a stated time may entail the payment of a considerable stipulated forfeit, or, what is the same thing, may cause the loss of valued customers.

It may be urged that as two engines have twice as many parts as one, there is more liability to breakdowns with two than with one ; but against this it may be said truthfully that where there are two (properly disconnectable) there is better opportunity than where is only one for fixing either one of them at once anything give signs of being about to go wrong. As soon as a thump is heard, or a whiff of steam is seen at the stuffing-box, the engine thus offending (or offended against, as the case may be) can be thrown out and fixed, and no one outside the engine room be *the wiser.*

This assumes the two engines to be so connected with each other and with the work that either may be thrown out without interfering with the establishment; and that this throwing out may be done by one man, in a few minutes, and preferably while the good engine is running. Such connection is not found in one plant in twenty, where there are two engines, yet it is simple enough. Where there are two engines, one right hand and the other left hand, driving a shaft in common, bearing one fly-wheel between the two engines, there may be a friction clutch or other clutch between each crank and the common fly-wheel (which is assumed to be belted). Where there are two engines, each with its own fly-wheel belted to a common jack-shaft, there may be two clutch pulleys on the jack-shaft, and throwing either of these out will permit the stoppage of the engine from which it takes off power. Throwing off one of the two main belts would accomplish the same result, but with heavy belts this is a difficult and even dangerous operation, and getting the belt on again is no slight task.

Where there is no jack-shaft, but the two engines drive two pulleys on one end of a line shaft, a clutch between the two pulleys permits throwing out that engine which is toward the end of the shaft.

Where the pair of engines is at or about the center of length of a long main line, and there is no jack-

shaft it is comparatively easy to throw out either end of the line by breaking a coupling joint between the two driven pulleys, and this will permit driving one end of the mill while the other rests. Compression-hub pulleys also give good facilities for throwing out either engine in such case ; and where either engine alone cannot give out enough power to drive the whole mill, the establishment will have to be thus broken in half down the middle, as far as driving is concerned.

Disconnecting either engine at the crank-pin is not practicable while the engine is running, and does not permit doing anything to the crank-pin or the main journal and bearing ; besides which it requires the services of more than one man, on an engine of any size, and some engines are so unfortunately proportioned that the connecting-rod must be disconnected at both ends in order for the crank to clear it.

Take it all in all, in most establishments using from 100 horse power upward, it will be found advantageous to provide two engines instead of cne ; and whenever there are two engines, either one must be disconnectable without throwing out a single machine unless desired.

Governor.

There are some types of engine which permit the *buyer to* have his choice of governors. In such cases,

he seller of the governor should be made to give such guarantee as to speed, the same as has been already laid down; and the builder of the engine should really be released from any responsibility in the matter, particularly if he does not recommend the governor selected.

Piston Packing.

As a general thing the builders of an engine put in that packing which they find will do creditable work therein. If they sell you their engine under guarantee they are interested in having a good packing, for a poor one may waste ten to fifteen per cent. of the steam either by letting it blow through or in excessive friction; which latter not only costs money for steam but calls for reboring the cylinder too soon. As with other matters, don't try many experiments with piston packing. See that what you have is properly adjusted. If it can be adjusted by hand see that it is set out just far enough to prevent steam from blowing through (which the drip cocks will show very soon) and yet that it is not set out so far as to add to the friction of the engine.

Rod Packing.

The engineer is bothered to death with rod-packing *salesmen. About* one half of the patent packings

the market are not worth the paper that it takes to wrap them up. For small engines good Italian hemp, braided up with black lead and tallow, will do good service at little cost ; and even in some large ones has been found to do as well as many of the patent affairs ; but for large engines it is well to use some one of the best known patent or specially-made brands. The rule for tightness is the same here as for piston packing : it must just barely not permit blowing through. Any extra tightness beyond that point simply means extra steam taken to overcome the extra friction and increased wear of packing and rod. There should be no leaks or puffs of either steam or water from either the piston-rod or the valve-rod stuffing box ; each should give no signs of the rod playing through steam on one side and air on the other.

Fly-Wheel.

Don't be afraid to pay for a good big fly-wheel. The builder who has to guarantee regulation, will be only too glad to let you down easily in the price of the extra fly-wheel metal. The increased friction on the main bearing due to the increased weight, is much less than is generally supposed ; and there are few plants where the increased steadiness of regulation will not be appreciated. This will be especially the case in electric light plants, in paper or flour mills,

and in silk or other textile mills, where good regulation is absolutely essential to good product. The function of the fly-wheel is to slow up the engine when it commences to run too fast, and to help it along if it lags. It tends to run at a uniform speed by reason of its momentum or inertia. If the load remains the same and the steam pressure increases, the fly-wheel absorbs a great portion of the excess, thus making a trifling increase of speed out of what would otherwise be a marked hastening. If the load remains the same and the pressure decreases, the fly-wheel gives out some of the power which it has absorbed; thus very materially lessening the slowing up which would otherwise occur. If the pressure remains the same and the load increases, the fly-wheel, by its momentum, tends to keep the speed up to the standard. If the pressure remains the same and the load decreases, the fly-wheel, by its inertia, tends to prevent the engine running away. The lighter the fly-wheel, the more a given variation in load or in pressure will affect its speed, and the more the governor will have to do in the way of controlling the steam pressure or its point of cut off.

An engine with a very heavy fly-wheel may take a few more revolutions to attain its normal speed in starting up, and be a little longer in stopping when the throttle is closed at shutting down time, than one with a *lighter* wheel; but the more this is so, the

more closely the fly-wheel will keep to its standard speed despite variations in load or pressure, once it is saturated, as it were, with power.

Throttle Valve.

This seems a small item, but if your engine started to run away and you found that you could not shut it down by reason of the throttle valve sticking wide open, you would think that it was very important. It is well to have one which shuts with the pressure; in fact it is best to have two, one of them of a quick moving type, which will permit it to be shut off right away, almost with a single motion of the arm, and the other of the ordinary kind that requires several turns of the wheel to close it.

Condenser.

If you have plenty of water, it will generally pay you to put in a condenser when you first start out, making allowance for its capacity in increasing the power of the engine. If the load gets too heavy for the engine and there is plenty of water, it will usually pay you to add a condenser. But if your engine is loaded just right for the work it is doing, you will sometimes find that the condenser, so far *from increasing* the economy, will increase the coal

bill. In this matter, be guided by the advice of an expert not interested in the sale of condensers ; and do not ask his advice unless you give him proper facilities for basing advice upon. A regular test should be made, showing what the engine is doing ; this should be compared with what it is expected to do ; and these facts, taken into connection with the boiler capacity and duty, will govern the expert in his deductions.

Where you have to pay for the condensing water, make a contract for some years ahead, with option of renewal, or you may find yourself in the position of having to pay a dollar and a quarter to save a dollar.

Compounding.

Compounding, like adding a condenser, may or may not prove economical, according to circumstances. A compound engine may save coal right along without increasing the repair bill very greatly; or it may save but a very little and run you in for two kinds of extra cost. And there are cases where a compound engine will eat more steam than a non-compound. Compounding very small engines is out of the question; the extra complication and cost of the engine more than offset coal saving, should there be any.

Of course it is understood that a compound engine may or may not be condensing; and that a condenser may be added to either a compound or a non-compound engine.

The matters of compounding and condensing cannot be decided by horse sense, nor by what is usually called "practical experience"; nor will any general rule enable even the initiated to decide the question off-hand. Each case must be settled on its merits, and with a full knowledge of all the conditions ; and must be decided by a professional engineer. No mere starter and stopper, no plain engine-runner, can approach it properly. Even the average professional engineer often finds himself in a quandary when these subjects come up. If he does not, he should.

As this book is not for professional engineers nor for those studying to attain professional knowledge in that line, I do not attempt here to discuss the elements which should govern the choice. Suffice it to say that they exist, and are many and various; and that due appreciation of the kind and amount of influence exerted by each, calls for a high degree of knowledge and judgment.

Exhaust.

For non-condensing engines in cities it is well to ·e an exhaust head, which is a species of muffler

that deadens the noise of the puffs and carries the drip quietly away instead of letting it stray about and scald people. In some cities the use of such an appliance is compulsory.

Under no circumstances let the exhaust discharge into a brick stack or flue, as it will disintegrate the masonry. For the same reason it is well not to discharge it into a brick sewer. In the latter case there is the additional disadvantage of its encouraging further decomposition of the substances which the sewer is supposed to carry away.

Remember that the exhaust is a good indication of what your engine is doing. If it is "free," that is, if it discharges into the open air without the intervention of a coil of heating pipes or a condenser, a feed-heater or an exhaust head, the softness or the sharpness of its puffs indicate the absence or the presence of causes which produce back-pressure on the engine. A barking exhaust is a watch-dog, calling your attention to a thief who is making way with your money. Where there are regular puffs, at varying rates of speed, the engine speed is irregular ; the valve may be set all right, so that the distance between any two consecutive puffs is the same, but the number per minute varies from time to time. If the barks come in sets of two or of four, like the footsteps of a cantering horse, the valves are set badly, and the engine *may be doing* most of its work on one end. Soft,

gentle puffs, at regular and equal intervals, are the best sound, usually showing that the pressure at discharge is low, the valves properly set, and the fly-wheel and governor doing their work properly.

Safety Stop.

There are very few plants where it is not best to have a governor with a safety stop, by which, if the governor belt breaks or other similar accident happens, the engine will not run away, but will be stopped at once. Many of the high grade engines on the market have such safety stops ; and I am of the opinion that there should be a law compelling their adoption. The running away of an engine may wreck a building as completely as the explosion of a boiler. Many establishments have safety boilers but very dangerous engines.

Indicator.

On any engine from forty horse power up it will pay to have an indicator always on hand, if not always in place ; and the engineer who cannot take cards from it should be discharged and one got who can ; due attention being paid to the fact that the man who can take cards and read them properly is worth more than the one who can't. Cards should be taken

every day at least twice, where the engine is over forty horse ; and where it is over one hundred, it will be well to have them four times a day.

Where the power given out is about the same, year in and year out, it will pay to give the engineer a certain percentage of the saving in fuel ; that is, if the engine builder's guarantee, combined with that of the boiler maker, calls for an indicated horse power with four pounds of coal per hour, let the engineer have half or some percentage of all saved below three and three-quarters pounds.

The indicator will tell you more in five minutes about your engine and about the machines which it drives than you can learn in any other way in five hours.

It is well to call in the services of an expert, from time to time, to see if the engineer is keeping things up to standard, and if the machinery is doing as it should in the way of ease of running. The engineer may be very capable about the engine and yet not quite up in the niceties of how to find out the power consumed by any given loom or other machine ; and besides this, the indication by an outside party will be a check upon him. A capable engineer will invite such criticism ; a slouch or a conceited ass will resent it. When cards are taken it should be stipulated that both the engineer and the expert shall take them ; and that each shall have half of the other's cards if

he wishes them. The engineer or the expert who refuses this will be a good man to let alone. (In this connection read the remarks on the Dynamometer, on page 141.)

Oil Cups.

The old story, "For want of the nail the shoe was lost, for want of the shoe the horse was lost," is paralleled in the case of the oil cup. A poor cup can do much to ruin an engine or a machine; a good one do much toward bringing it up to the highest standard of duty. In this matter do not try experiments rashly. You may try one cup against another in some place where heating will not do serious damage; but don't fit out all the way through with any untried cup, no matter what is promised for it. If the new cups are better than the old ones, it may pay you to take off the old ones and put on the new ones. If they are not better, there will be no advantage to you in trying the new ones. It never pays to take a risk, however slight, unless you are paid to take it.

Sight Feed Lubricators.

The invention of these has been a great blessing to the engineer and to the engine owner. There are *many good ones* and some which are not fit to throw

at a cat. Get some style which you know to be used in establishments proverbial for their good condition and economical running ; and see that they get good oil. Paying two dollars more for a lubricator will not always enable you to save half your oil bill, nor to run with poor stuff that has neither body nor anti-friction qualities. (Oils and greases for lubrication are treated under a separate heading, on page 138.)

Engine Room.

As to the engine room. Do not get the idea that any place at all is good enough for the engine and the engineer. Particularly, be generous in the way of light and air. No man can do good work for a long time in an unfit place. The engine room should have a high ceiling and abundance of light, preferably from the side ; and if plenty of fresh air does not come in through windows, make arrangements for getting it in through some other channel. The walls should be of a light color ; the floor should be a good one ; and your engineer should be made to understand that he must keep everything in the room clean and bright. He should have a desk and writing materials and a good locker, and be made to feel that good work is expected of him and that no one *will be allowed* to meddle with him.

The Cost of Your Fuel.

If you are producing some one kind of product, as flour or textile fabrics, paper or rails, figure up at the end of each month how much fuel and how much oil it has taken per thousand yards of cloth, per hundred barrels of flour, or per hundred tons of rails. This is, of course, an element of cost which you should know; and in case of a rise or a fall in the price of fuel you can be governed by it. Besides this, if the amount changes from month to month,—and particularly if it increases with the advent of a new engineer or a new fireman,—you should let yourself be heard on the subject. (See under head "Log Book," page 129.)

The Engine Runner.

It is the engine runner's place to keep the speed of the engine steady. If you have a good engine and governor it will do that itself; but if you have not, he must watch the cut off and the throttle, and perhaps the governor, to see that the speed indicator shows regular turns all day long, every day in the week. He should be allowed a reasonable time to get the hang of the work; be told in advance about when the *greatest* special demand for power will come, and *about how* much it will be. If he has an indicator

he can soon post himself thoroughly as to what is coming and when it is expected; and should then govern himself accordingly or quit.

In hiring an engine runner get one, if you can, who can make his own repairs; but remember that you hire him only as an engineer, not as a machinist. Let his ability as adjuster or machinist or carpenter, or whatever trade knowledge he may possess, be reserved power; don't make him a man of all work, to tighten all the belts in the establishment, and do the steam fitting, and cut bolts, and grind planer-knives, and mend holes in the tin roof, and paint the office-walls, and all that sort of thing. If you do he will be very apt to neglect his engine either intentionally or by reason of being everywhere except where he should be; and some day you will have the crank pin seized fast, or the cylinder head knocked out, or the fly-wheel off with a bang through the roof and walls, and you will wish that you had let the engineer stay where he belonged. My advice is to get a man who can do more than merely start and stop his engine; then, save his extra powers for an emergency.

As to wages. Pay your engine runner what is right; and at Christmas, if he has been faithful and economical, see to it that a fat turkey finds its way to his house; and at other times show him that you do *not consider* the arrangement between you as simply

so much work and no more for so much cash and no more.

Take a paper devoted to power, and after you have read it let the engine runner have it to file in the engine room

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Wind Power.

The fact of the windmill having been one of the earliest motors leads many to imagine that it has no place in the economics of the present progressive day; but it still offers a convenient and inexpensive power for certain purposes,—as pumping water,—and there are many steam plants where it would pay to put in windmills for this purpose, because under most conditions wind is cheaper than coal. The evolution of the storage battery, by which electricity may be generated when power is active and used when it is passive, gives the windmill a chance in the electric lighting field.

The windmill may be relied upon in most localities to average eight hours of work per day ; and can be used for two classes of work—those like pumping, wood sawing, feed cutting, etc., where intermittent work is satisfactory ; and those where accumulation is practicable, by pumping water into a reservoir, compressing and storing air, and driving dynamos *which* charge accumulators (storage batteries).

Working an average of eight hours per day, and with wind at sixteen miles an hour, an 8½-foot wheel has raised 3.016 gallons of water per minute, or 1447 gallons in the eight hours, 50 feet high; being a duty of 0.04 useful horse power. A 16-foot wheel raised 31.654 gallons a minute or 15,194 gallons in the eight hours, the same distance; equal to a work of 0.41 horse power. A 25-foot wheel raised 106.964 gallons per minute, or 51,343 gallons in eight hours, the same height; the work done being 1.34 horse power.

Counting as items of cost, interest at five per cent. per annum on cost of windmill, pump, and tower; repairs and depreciation another five per cent.; attendance and oil, the 8½-foot wheel cost 15 cents per hour per horse power; the 16-foot wheel, 5.9 cents, and the 25-foot wheel 3.2 cents.

Averaging results the windmill has been shown to be about fifty per cent. more economical than the steam pump, even when no charge is made for attendance and boiler capacity for the latter prime mover. —(*Wolff*).

Water Power.

While steam is the motive power *par excellence* of the present day, we must not forget that many of our busiest and most wealthy communities have built up their importance and prosperity, by reason of the

water power which drove their mills and factories. While many of these water power mills are putting in steam as an auxiliary, owing to the falling away, the unreliability, or the insufficiency, of the water supply the makers of water mills are busier than ever, and countless thousands of power plants now have, as they will have in future, water as the only motive force. It is then desirable to consider what conditions are favorable to the use of water power; what water motors are offered, and how they should be chosen and used. It is also well to look into the question of combined plants—where steam is used as auxiliary to water power—in time of drought or of low water.

Water Wheel.

Those water motors which always have their axes horizontal, discharge the water on the same side as that on which they receive it, and are comparatively slow moving (generally called water wheels) are divided into overshot, in which the water falls upon the radial buckets at a point above the highest part of the wheel, and as the name implies shoots over the wheel; breast, or middleshot, in which the water strikes about mid-high and goes under; and undershot, in which it passes under the wheel, acting by its *current* only, instead of, as in the other cases, acting

by weight and impact. In undershots the sheet of water is kept close to the wheel by a curved apron.

These wheels are best adapted to utilizing large volumes of water at slow velocities or having but slight head; and go best in mills requiring slow shaft speed, as for high speed machinery the cost, complication, friction, and liability of break downs is increased by the necessary speeding-up gears.

Turbines.

Water motors having comparatively high-speed motion about a generally vertical axis, which discharge the water on the side opposite that at which they receive it, and which act by the impact of the water, and by reaction, are called turbines. They are now often set with horizontal axes, particularly where two are used. They are particularly adapted to high heads and small volumes of water; a comparatively small motor often yielding a surprisingly great power; thus one $12\frac{1}{4}$ inches in greatest external diameter yields 47 horse power under 354 feet head; the water having a velocity of 115 feet a second, and the wheel running 2300 feet a minute.

Some turbines are noted for yielding very high duty when the water supply is full, but are uneconomical when the water is limited; others are just the other way; *while* some, again, have a fair efficiency under

almost any set of conditions. Some, again, have but low duty, yet are so strong and simple as to be practically unbreakable and underangeable in use. A Minneapolis mill owner once said to a turbine manufacturer who vaunted the high duty of his wheel, "I don't care anything about duty. I have water to sell and water to give away. What I want is a wheel that will let a saw-log run through it without breaking the wheel."

The power user who contemplates using water will see that common sense and a knowledge of the conditions should be his principal guides in selecting a wheel.

Governing Water Power.

The attachment of a governing device to a water wheel proper (overshot, breast, or undershot) is none too feasible; but turbines are in this respect very tractable, and may be (although they seldom are) governed nearly as well as steam engines. By reason, however, of the fact that the small sizes are nearly as economical in water per horse power as the large ones, and that few of them, large or small, are as economical at one "gate" or amount of water supply as at another, it is often best to have two or more wheels, any one of which may be thrown out at will, by hand. Thus a *30-horse* and a 50-horse wheel will give 30, 50, or 80

horse, at will, with full gate; at less gate for one or the other there may be given 20, 30, 40, 50, 60 or 70, horse. A set of 30, 40 and 50 give at full gate, 30, 40, 50, 70, 80, 90, and 140 horse ; and at less gate for one or more, anything from 20, or even 10, up to 139.

Combined Power.

So many of the water mills in this country are supplementing their water wheels or turbines with steam engines that the best method of coupling these together and governing them has begun to be studied by millwrights and engineers. We assume that every turbine requires a governor, but very few water wheels are thus supplied ; and this being the case it can readily be seen that diminution of the load, without any lessening of the water supply, throws on the engine governor the entire duty of governing. Thus, if the water wheel is supplying 200 horse power and the engine 100, and the load drops from 300 to 250, the engine has to be cut down to 50 horse power, or 50 per cent. lessening of power for $16\frac{2}{3}$ per cent. lessening of load; while if the load be cut down to 200 horse power, the engine must be completely thrown out; a reduction of 100 per cent of power for only $33\frac{1}{3}$ per cent. less load.

Also suppose that the load remains constant at 300 horse power, and the water supply drops from 200 *horse power to* 150; the engine is then called upon

to supply 150 horse instead of 100; an increase of 50 per cent. in engine power without the real load having increased at all.

Without going into mechanical and technical details, which I have attempted to avoid all through this book, the power user can see that the problem of governing a combination of engine and turbine wheel is more difficult than that of controlling the power and speed of either one of these motors alone.

The best way is to rely very largely upon the plan spoken of under the head of "Turbines," page 115; having two or more wheels or wheel sections, and trimming down or opening out on one of these at a time by hand for coarse adjustment; leaving to the engine governor the minor regulation. Thus if the wheels or wheel sections were of 50 horse power each, at a certain head and pressure, and 60 horse power was withdrawn from the load, cut out one wheel and let the rest run at full capacity, trusting to the engine governor to reduce the engine power ten horse. If the head lowers gradually, (1) trust to the engine governor's quietly opening out the throttle or making the cut off later, up to that point at which the engine worked uneconomically by reason of excessive load, and then throw in another wheel; or (2) throw in another wheel and let the governor cut back (up to the limit of low economy from under load), letting the engine gradually open out as the water lowered.

Here is a case where the engine runner must be of a high order of intelligence and competence ; for he must know what are the engine's limits of economical working, and what are those of the water wheel ; he must know the cost of ten horse power, and of a hundred horse power, produced from coal or wood and from water, and must, between two evils of low duty, choose the least, at the same time not losing sight of the fact that in many mills and other establishments regularity of rotation speed may be of even more importance than fuel saving.

Here is where the advantage comes in of having an engine runner who can use the steam engine indicator, and of having such an engine runner keep a daily or even hourly log book in which the horse power and the efficiency of each motor are entered for comparison.

Electric Motors.

The electric motor has an excellent chance to win for itself great popularity and success. Whether it does or not depends more on itself and its owners than on power users, who are more than favorably inclined to it. Some one once said that almost anybody could sell a man a heavy overcoat in December, but it took a very smart salesman to sell one in July. The idea is that people readily buy things which they *really need*, and those in favor of which they are

favorably disposed. The electric motor is one of those things which people like and need. It is clean, quiet, compact, and not bothersome; will go in almost any corner of floor or ceiling, or fit on a shelf. The only things that the power user has to consider is, "How much is my power going to cost me a year, and will the thing run exactly as I want it, whenever I need it?"

The question of dollars and cents is readily settled by any one who knows how much his steam power costs, asking an estimate for a motor to run the same plant the same number of hours a day, and comparing the two. This is a case where I can say little or nothing. Each establishment will have to be estimated on separately. Both factors—particularly the cost of the steam power—are very variable.

Where the engine and boiler (or the engine without boiler, where steam is taken from a steam supply company) require a separate attendant, the advantage is more apt to be in favor of the electric motor. Where the engine and boiler receive scant—although perhaps sufficient—attention from some one who does not draw wages for such work, and whose general usefulness in other ways is not impaired by such attention, the motor will have to stand more purely on its own merits as saving the smell, heat, noise, and dirt, which in greater or less degree characterize the use of steam power.

There are hardly any two cities where those furnishing electric power charge the same price per year for horse power. True, the price of steam power varies also; but the limits are generally $50 (perhaps $40) per year per horse power for large amounts, and $100 per year per horse power for small ones. The extremes for electric power certainly vary more than this.

Renters of electric power for elevators must remember that some makers of dynamos and motors, and some power supply companies, "bull" their stock by the statement that such companies can actually rent more power than the maximum which the dynamos can furnish; the idea being that elevators are charged with the power requisite to make the up trip, loaded, and that on the down trip the elevator becomes a source of power, reinforcing the supply current by an amount equal to all the weight lifted, so that of the entire amount charged, all is restored except that used in overcoming friction in the motor and machinery, and internal resistance in the former.

Electric motors do away with all work and dirt of handling coal and ashes; and are essentially "top story motors." They are free from smell and should be from noise; the danger from shock is largely mythical and not to be named in connection with even the slight danger from explosion of a small steam boiler; little or no skill and intelligence is required to run them; they start out at once with full

power and cost nothing (but perhaps interest and insurance) when lying idle ; require no pipe or flue connections, and altogether should prove the motors of the future if the dollar and cent part of the problem can be made to come out right. As I said before, that must be worked out separately for each particular case.

Gas Engines.

The gas engine—which uses the force produced by the enlargement of volume that takes place when gas and air combine in burning—exists in many forms, some of which are complicated and fairly economical of gas, and some of which are extremely simple in construction but wasteful of gas. There are a few which are so simple that, if they are run according to instructions, any careful and intelligent but unskilled attendant can keep them in good order. The greatest disadvantages of all gas motors are inseparable from the principle of having the fire in the engine instead of under water in a boiler, the necessity for the employment of very large cylinders for a given power, and the impossibility of reducing the waste of power by friction down to anywhere near as small a proportion of the entire power generated as in the steam engine. The necessity of employing a water *jacket, with* cold water circulation, is a disadvantage

which it shares with some hot air engines, without, however, experiencing, as the latter do, a waste of heat from this cause.

Where power is used intermittently and the periods of rest are long as compared with those of work, the gas engine is a desirable motor, as it burns no gas when not running, yet may be started up to full duty, or completely stopped, in a few seconds. This quality it shares with electric and water motors, and those hot air motors which burn gas. Where run most of the time, however, the much greater cost per horse power for gas over that for coal makes a small steam engine, or some other motor, preferable. The noise and smell of some gas engines are very objectionable when they are placed where this element has any importance. The gas engine being single-acting is another reason for its being so large and heavy for a given power; this feature necessitating not only that the cylinders shall be double the size required for double-acting engines, but that the fly-wheel be much heavier. A pipe for the gases of combustion should on no account be omitted.

Hot Air Engines.

Hot air engines, often called caloric engines, do in one sense just what the gas engine does, except that *they use coal or* coke instead of gas as a fuel. In

another sense most of them act as steam engines do, as the gases of combustion do not enter the cylinder, but air is heated by the fuel just as water is heated in the steam boiler. There is no explosion as in gas engines. We find in all hot air engines the disadvantage that they require an air pump nearly as large as the working cylinder. Only those act economically which compress the air considerably. The size necessary for a given horse power is very great and lubrication of such hot machines in difficult. Those which burn coal or coke cannot be started and stopped so readily as gas engines. Of course they can be used where gas, electricity, or water is not laid on, as would be required for gas engines, for electric motors, or for water motors. Few require circulation water. Where coal or coke is used, there is the nuisance of bringing in the fuel and removing the ashes, and of course a fire requires attention, while a gas jet needs none. Those which use coal or coke give off little or no smell. All require pipes for the gases of combustion.

Water Motors.

Few who scout at the idea of a water motor stop to consider that a hydraulic elevator is practically just that thing, and that they have found water power a *convenient* substitute for that furnished by a steam

engine and boiler, or even for a steam engine taking steam "from the street," as the phrase goes. The water motor matter must be decided on its merits in each case, entirely independent of any other. A water motor may, where the pressure is high, be quite small for the power it gives; but the tenant on a top floor of a high building might be surprised at the size of the one which he might need for the same amount of work as was done by quite a tiny machine in the basement.

Some of them work very economically of water, being practically the same thing as a piston water meter, turned "the other way to"; others will take double as much water under the same head to produce a given amount of power. Some will be quite economical of water under certain heads, and be very wasteful at higher or at lower pressures. Some will give no trouble at all with good water, but the presence of mud or of grit will lower their efficiency and increase their repair bills. Some will give a good duty at certain speeds but at higher or at lower speeds will be wasteful. Some are quiet, some are unpardonably noisy. Those which are the most economical of water are generally the most complicated, and give the most trouble with muddy and gritty water. All yield full power in an instant, and as promptly stop using the motive fluid when not needed.

So it goes; there is no general rule; all that I can

do is to warn the buyer to look into certain points and demand certain guarantees.

It hardly needs telling that the water motor dispenses with smell, heat, ashes, and the necessity for attendance.

Guarantee.

Whatever you buy,—waterwheel, electric motor, boiler, engine, or appliance for any one of these, see that you get from some responsible person a written guarantee that it will do what is claimed for it. Of course, if impossibilities are claimed, there will be no use in having a guarantee ; but there are many cases where you will save yourself considerable time and expense if you refuse to put anything in without a guarantee that it will do what is claimed of it or what you want of it : and refuse to pay for it until it has been shown by sufficiently long trial, under practical conditions, to do all that is guaranteed.

A water wheel should be guaranteed to develop a certain net horse power by the brake, under a given head, and with a stated number of cubic feet of water per minute ; and its duty at half gate and at three quarter gate should also be guaranteed.

A boiler should be guaranteed to evaporate each hour a stated number of gallons of water of a certain *temperature,*—in the way of capacity ; and to do it

with a certain number of pounds of coal of some stated kind, in the way of duty.

An engine should be guaranteed to produce a certain minimum horse power (indicated or shown by the brake, according as the terms may be), at a stated number of revolutions per minute, from steam at a given steam-chest (not boiler) pressure—this in the way of capacity ; and to do it with a certain consumption of dry steam (the pressure named in the capacity guarantee) per hour per horse power—this last in the way of duty.

The engine should also be guaranteed to run at a certain number of revolutions, with not more than a stated percentage of maximum variation in case the pressure is increased or diminished twenty-five per cent. or in case the load is increased or diminished fifty per cent. ; and the percentage of maximum variation should be guaranteed for both those variations of both load and pressure at once—that is, if the pressure is increased twenty-five per cent. and the load suddenly diminished fifty per cent. the engine should not increase its speed more than, say, two per cent.

The engine should always be guaranteed to run without repairs due to fault in design or construction, for a certain term of years. I do not fill in this term, because makers vary greatly as to how long they will guarantee their work under equal conditions, and each *sensible*, honest, and competent builder will

adjust his guarantee, in this as in all other respects, to the conditions under which the engine is to run.

An electric motor hired from a power-selling concern should be guaranteed to deliver at any time a stated net horse power by the brake, at the rotation speed at which it is guaranteed to run steadily. It should be definitely agreed upon and expressed, who is to pay for lubrication and repairs, and who is to attend to them; and there should be a penalty attached for non-action.

Where the power-selling concern sells horse power to be delivered by motor and charged for as used—that is, the tenant to pay so much per year per horse power, the amount to be averaged or measured, it is safe to trust to the current meters used by electricians, which show how much current has passed into the line supplying the tenant, by showing how much has passed, under exactly similar conditions, through a wire having a cross-section bearing a certain definite proportion to that of the wire supplying the motor.

Wages.

This is a very ticklish question, because in these days certain workmen are trying to persuade employers to pay fixed rates for very variable services. But as a broad, general principle it may be said that *you can* afford to cut down your wages almost any-

where but in the engine room or boiler house ; and no matter whether or not you pay the Union scale, it will generally pay for you to give a premium on saving of fuel and oil.

Log Book.

No matter what wages you pay,—be they high or low,—see that your engineer keeps a log book in your interest, recording coal consumption, horse power, etc., regularly, for each day in the year, with comments on the work done. In the market there are books for this purpose ; one of them prepared by myself.* Either of them, if properly kept, should result in the employee saving money for his employer. Refusal to keep such a log by an engineer who has time and facilities for keeping it, should be cause for an investigation on your part.

Shafting.

Do not try to get shafting too cheaply. There is cut-throat competition among those makers of it who turn it out in immense quantities, and who are equipped with special appliances for making up at a mini-

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* Engineer's Hourly Log Book. Blanks for three months' record, with instructions, information, tables, etc., price 50 cts. *To be had of the Practical Publishing Co., 21 Park Row, N. Y.*

mum cost the stock which they buy in very large quantities. If you get down much below their prices you are apt to strike either poor stock, or shafting that is not straight, or not true, or not even in size. To find one end of a shaft larger than the one which goes in the other end of the coupling, or even larger than the other end of the same piece, is exasperating, and sometimes expensive. Buy shafting that has a finish upon it; do not have any part of it turned down for journals; then you can use any part of it either as a journal or for holding a pulley.

Cold-rolled shafting has a beautiful finish and is very strong and light, but cannot be "splined" without curling.

If your shafting is sprung it will do one of two things; make your belt-driven machinery run jerkily, or consume power in being bent back and forth every time it turns. It may do both. In any case it will pay you to see that every line when put up is perfectly straight and true, and that it is kept so.

Remember that the sudden addition or removal of a heavy load from an upper floor may spring a line of shafting and give trouble. Sometime after it is in good shape a load of lumber on the floor above will be removed, allowing the floor to rise; sometimes the load will be put on afterward. These things should be looked after, and if such occurrences *happen*, the floor should be shored up from below, or

hung by strong iron rods from the roof or from a beam or truss thrown across to bear its weight.

Shaft Couplings.

Plate couplings, while very strong, are also very heavy and very expensive ; and there are few places where a good compression coupling would not do much better. The compression coupling has the advantage of not marring the shaft, and, if properly made, will allow for trifling discrepancies in the diameters of the two adjacent shaft ends. Select a type that can be readily unfastened as well as readily applied.

Hangers.

Whatever hangers you get, let them be adjustable, not only in height but by ball and socket. The saving by decrease of friction alone from this cause will be considerable in most establishments. There are few plants where floors do not sag, and where the adjustable ball and socket feature is not a good one to have. Hangers are best "open," so that they will permit any length of shaft to be taken out without backing down the whole line—an operation which is *often very* expensive, not only in the labor consumed

in effecting it, but by reason of the job throwing operatives and machines out of work.

Clutches.

There are not enough mills and shops well supplied with clutches. They are very convenient in enabling any part of a long line to be shut off from the rest. There are many cases where only one room or part of a room is run at night, but where it is necessary for the whole line to be run and oiled; proper clutches would do away with this. Few manufacturing establishments have half enough attention paid to this matter; and an immense amount of inconvenience and loss is the result. A certain amount of experience and skill is required to locate them properly, but, once placed, they yield much advantage to all concerned.

Pulleys.

Pulleys which are heavier on one side than on the other, or which are out of center on the shaft by reason of having too large a bearing and of being put on with set screws, give irregular running of the machinery and do not do any good. They also tend to spring the floor and jar the building. Make whoever sells you pulleys guarantee that they are in perfect running balance. Standing balance is seldom

any good. No one uses pulleys when they are not running. They should run smoothly and quietly at the highest speed at which you intend to use them.

Split Pulleys.

The greater proportion of split pulleys you have about your plant, the better it will be for you and the better you will like it. They can be put up, taken down, or moved along on the shaft with so much less trouble than the "solid" type, that in most establishments they are very desirable. They are, too, very much more readily handled; each half being, of course, only very little more than half as heavy as the solid pulley of the same diameter and face.

Belts.

I suppose that there must always be some trades which will serve to yield a livelihood to supply-agents. The belt business seems to be one of those trades; and the principal reason for it is that few belt users know how to tell a good belt from a bad one, or would pay for a good one if they knew it, or would take care of it properly if they had it given to them. This is plain English, but it is cold fact.

John Randolph of Roanoke once said, "Our boys are *not well* educated, but our girls will never find

it out." The average belt is a poor one, but the average belt buyer will never find it out. If you want 40 and 10 and 5 and 2½ per cent. discount, you will find belt makers and dealers who will accommodate you; but "discount belts," are not so good as those which are bought at a good price. Almost every manufacturer makes two or three grades, and as a general thing the purchaser who gets the best discount gets the poorest belt. In this the belt buyer must not blame the belt dealer quite so much as he must blame himself.

See that you get a belt wide enough for your work, and run it fast enough to enable you to get out of it what horse power you want, without unduly straining belt or fastenings. Buy from a reputable dealer. Buy only those brands which are made by houses having the knowledge and facilities for making good belting.

As to whether you shall buy leather, or rawhide, rubber, cotton, or compound, or shall skip them all and put in wire rope or Manila rope, don't ask me or any one else, without stating the conditions. Some of these cannot be used under some circumstances, at all. With others it is even up which you buy; any kind is likely to be better than the care that it will probably get.

If you buy leather belts, stuff them well with castor oil from time to time, after washing them with soap

and water. If you use rubber, keep all kinds of oil from them ; wash them with soap and water or soda and water if they get glazed. Do not put printers' ink or anything like that on any belt. See that they have a good wrap around both pulleys; that costs little or nothing and adds to the driving power. See that they are so laced or otherwise fastened, as to give equal strain all the way across. Don't let steam or hot water get on any kind of a belt. Run your belts as slack as you can without their flapping.

Every belt must be absolutely uniform in width, texture and thickness all through; and it must be straight. If it varies in width or is not straight, it will "weave" on the pulley ; if of varying thickness it will give the machinery a varying velocity; and any one of these defects may cause it to flap.

In buying a cemented leather belt, be sure that it is guaranteed to stand dampness; for although dampness doesn't do a leather belt any good, it must be prepared to stand it in case of a long spell of rainy weather, or if a steam leak should take place near it.

Belt Fastenings.

The best fastening is none at all. Where you can, have your belts made endless. If you buy of a reputable maker, and don't strain the belt too much, there *will be no* excessive lengthening; and if there is, in

most cases an idler next the small pulley will take up the slack and give you the advantage of increased arc of contact.

If you use fastenings, remember that the entire strain of transmission comes upon them. They are not apt to be more than one quarter, or at most one half, as strong as the belt itself ; put them in carefully, with a view to their carrying their heavy load evenly and constantly.

Rope Transmission.

There are cases where a half inch Manila rope will drive where an eight inch flat belt could not. Rope drive is particularly desirable where one shaft is directly above the other and very near it ; also where the distance between shafts is very great. Ropes have the merit of being cheap and readily spliced; they can be run round any kind of a corner, and are altogether very satisfactory for many positions. But there may be cases where rope transmission would be an utter failure; weigh the matter carefully.

Boxing-in Machinery.

In almost every line of manufacture there is risk of employees getting caught in the machinery ; and this *is particularly* so where there are children or women.

For humanity's sake as well as to avoid suits for damages, see to it that all belts and gears which are liable to catch in clothing are boxed in or screened with wire netting; and if possible have things arranged so that the engine can be stopped at once, by signal or by actual shutting off the steam supply, from every room in the establishment where such accidents are liable to occur.

Friction.

There is no such thing as machinery which will run without friction ; but there are such things as machines which have from ten to one hundred per cent. too much, and which are eating up their owners' profit. Friction means two things ; waste of power, and wear and tear of the rubbing parts. Both of these are paid for by the power user, without getting anything in return. An indicator card showing the friction of the engine and all the shafting and machinery which it drives, may be very readily taken in most establishments ; and if such a card, taken at the regular speed, shows forty horse power, that means that it costs you from 120 to 400 pounds of coal per hour, to say nothing of the extra wear and tear of boiler and engine, and all their appurtenances, and of shafting and accessories, just to keep things going, *without doing* a cent's worth of work. If you can

reduce that by twenty-five per cent. you will be saving from 30 to 100 pounds of coal per hour, 300 to 1000 pounds per day of ten hours, 1800 to 6000 pounds per week of 60 hours, 45 to 150 net tons per year of 300 ten-hour days. Count this up with coal at the rate which you are paying, and see if it will not pay you to keep things running smoothly.

Oils and Greases.

Here *is* a problem! Of all the oils in the market, good lard and sperm are the best for all-around work. Of all the greases, those containing good graphite (plumbago, black-lead) are apt to be the best unless they are to be fed through fine holes and passages. Bear in mind that small high speed journals require a different oil from those which run slowly and have heavy pressure upon them; that sliding surfaces (like guides) will not always do well with the same oil which will do for crank pins; and that steam chests and cylinders, particularly if the pressure is high, require an altogether different oil from that needed on cold places like journals and slides. Whatever oil you use, see that you use plenty of it (you can recover it, filter it, and use it again); and with free lubrication, see how much of some well-known brand it takes for a month to keep everything cool. If you *find that it* takes too much, you may try some other

well-known brand; for there is no one brand which is best for all conditions. Keep a record of the amount with the new kind, and if the cost is less and the result good, you have probably done well by changing. If you find the oil bill higher for the same degree of coolness, you have not done well in changing to that brand; it may be well to try some other yet.

Remember that gallons of oil have nothing to do with the matter; the thing to be considered is, How much is the bill for enough oil to keep everything cool and uncut? As for comparing an oil that does not keep things cool with any other, that is out of the question.

Bearing Metals.

After all is said and done, the regular old-fashioned Babbitt metal,—that is, Babbitt's own metal,—is as good as any one need want for any except the very heaviest bearing. This is not a cheap material. You cannot buy eight pounds of it for a dollar, as you sometimes see advertised. The following is the formula to make it: Melt four pounds of copper; add, by degrees, twelve pounds of best Banca tin, eight of antimony, and twelve more of tin. After four or five pounds of tin have been added, reduce the heat to a *dull red, then* add the remainder of the metal as

above. This composition is termed "*hardening.*" For lining, take one pound of it, and melt with it two pounds of Banca tin.

Lubrication.*

Never let a bearing squeak two days hand-running. If you hear a noise from it one day, that is the day to stop it. Every day that it squeaks it is telling the world at large that you don't know any better than to pay for power to wear away your journals and bearings.

Have your lines of shafting oiled at regular intervals by some one person whose duty it is to see that it is done. "What is every one's business is no one's business"; and that is true of oiling up more than of anything else about the place.

See that there are no places where oil will sling or drip where it should not go. Such slinging and dripping are wasteful of oil and damaging to property. There should be splash-boards to catch the oil which may be thrown from crank pins or other rapidly rotating members; and drip-pans to catch what falls from hangers and overhead bearings. What oil has been used between the wearing surfaces should be caught, saved, filtered, and used over again. When

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* See also under "Oil Cups," page 108; "Oils and Greases," *page 138*; and Friction," page 137.

it has been used too often as a lubricator for bearing surfaces, there are other uses to which it may be put—as in bolt cutters, etc.; or it may be sold.

"Dynamometers" or Power Scales.

It is just as practicable to weigh or measure your power as your coal or oil. In order to get power, or do work, there must be a push or a pull; this must have a certain force in pounds and be at a certain rate of speed per minute. What constitutes a horse power is treated under that head, on page 87; how to measure power is the subject of these paragraphs.

There are two kind of power-measurers independent of the steam engine indicator. Both of these employ actual weights to measure the push or the pull, and deal with the actual speed at which the push or the pull is made; but while one absorbs or destroys the power, the other passes it along. The first class embraces the power brake, called by professional engineers the Prony brake, from its inventor,—the second comprises transmission dynamometers, of which there are several varieties.

The Prony Brake.

The Prony brake consists of a clamp applied to the fly-wheel, pulley, or shaft, the power transmitted by which it is desired to measure or weigh.

To the elamp is attached a horizontal lever, which by the rotation of the wheel, pulley, or shaft is made to just barely lift a weight, to pull vertically on a spring balance, or to press vertically upon the platform of a platform scales. The pounds push or pull, multiplied by the speed in feet per minute at which such push or pull is exerted, and divided by 33,000, gives the horse power. The speed is got by multiplying by 6.2832, and by the turns per minute, the distance in feet from the center of the wheel, shaft, or pulley, at which the weight or cord is attached, to the horizontal lever. Thus, if the pull is twenty pounds, at a distance of five feet from the center of a shaft making 330 turns a minute, the power is $20 \times 5 \times 6.2832 \times 330 \div 33{,}000 = 6.2832$ horse.

This method is applicable to determining the net power given out by a motor, a belt, or a shaft.

Transmission Dynamometers.

The transmission dynamometer, or "power scales," measures the power which is passed through it. There are three general types: those in which the power is passed through it by a belt, those in which gears are used, and those in which the push or pull is measured by the degree of compression or extension of a spring through which it is passed. The latter is he most simple and the most common. In the first

two, a belt from the motor or the driving pulley drives one pulley of the power-measuring machine, and another carries the power from the dynamometer to the machine or the shaft to be tested as to the power required to run it. With the third kind, either the power is belted in and out, as just mentioned, or it is inserted like a coupling between two lengths of the line of shafting to be tested. In some of these, a dial or other scale points to the number of pounds push or pull; this, multiplied by the distance from the center at which the push or pull is applied, by 6.2832, and by the speed in turns per minute, and divided by 33,000, gives the horse power. A better graduation gives in the dial the horse power per shaft-turn, and this, of course, multiplied by the number of turns per minute, gives the horse power passing through the dynamometer.

Uses of Dynamometers.

It is of advantage to the power user to know how much power each machine he has requires at various speeds and with various degrees of load; how much each belt and line of shafting carries at various speeds; and how much power his engine gives out. By this means unnecessarily hard-running machines may be *improved or thrown* out, whichever is the more advan-

tageous; straining of shaft lines and of belts prevented or remedied, and overloading of the engine stopped.

Landlord and Tenant.

Between landlord and tenant, in power-renting cases, there are endless disputes, arising from two causes: ignorance of the facts, and lack of definite pre-understanding as to conditions and terms. There is no question but that landlords often overcharge tenants; and it is equally indisputable that tenants as often get more power then they pay for. In either case, the wrong is more often unintentional than otherwise. Every power lease should stipulate the maximum and the minimum horse power to be taken by the tenant; how and when it is to be measured; and where and how it is to be delivered. Omission of any one of these points offers a premium on a dispute and perhaps a lawsuit.

Whether the tenant pays so much per horse power, or so much per year for enough power to run his place, the maximum and the minimum amount that he is to have and pay for should be stipulated; because it is not reasonable that the landlord should have to deliver, on a short notice, or on no notice at all, more than a certain amount; nor is it fair to compel him to provide engine, shafting, etc., unless he is assured a *minimum* return. The lease should state whether the

horse power is "net," that is, exclusive of the power required to run the engine and shafting, or gross, that is, including one or both of these items. It should specify whether the steam engine indicator, or a transmission dynamometer should be employed to measure it ; and, if the latter, whether it is to be applied at the engine, or at the receiving end of the tenant's shafting. The times at which tests are to be made should be arranged—whether monthly, quarterly, or yearly ; at what time in the day, and whether with all the tenant's machinery on at once, or with an average load. The lease should also clearly specify on what days and between what hours power is to be delivered ; and what extra compensation is to be allowed for power and for engine-runner's services, in case of the tenant running on days or hours not specified in the lease. Where the landlord furnishes the shafting, it should be stipulated whether he or the tenant is to pay for and attend to its lubrication and alignment.

A tenant should not expect to get three horse powers for only one tenth as much as would be charged for thirty. He should not think that he should have an average of twenty horse with a minimum of ten and a maximum of thirty, at the same rate as where the extremes are less wide apart. Service on extra occasions is worth more than the rates charged at regular times.

The devices employed to measure power are described, in general terms, under the heads "Indicator" and "Dynamometers," page 106 and 141 respectively.

In making a power test, all the machines should be thrown off, and the power required to run the tenant's shafting accurately measured; then one machine at a time should be thrown on and the exact amount of power which it calls for carefully noted. In every instance the rotation speed as well as the horse power should be noted; and in the case of machines which have a varying feed—as, for instance, woodworking machinery, where the width of board planed, or the thickness of piece sawed, varies from time to time, the conditions should be noted. Other things being equal, the power required to run a machine or a line of shafting varies directly as the speed; thus, if a printing press requires three fourths of a horse to make 400 impressions an hour, it will need one and a half horse to make 800 an hour.

The method of estimating the power used by the belt width and speed, is very crude and unsatisfactory, as the driving power of a belt depends not only upon its width and speed, but on its thickness, condition, tension, and arc of contact upon the pulley; upon the material condition of the pulley, and upon other elements difficult to measure. Difficult cases, apparently the same, will vary 100 per cent. in the amount

carried by a belt; and variations of 50 per cent. between two persons' simultaneous estimates of the power carried by a given belt, are not uncommon.

And now I have said a good many things and left a good many unsaid, on the subject of the generation, transmission, and measurement of power. I might have been more positive and recommended certain practices at the risk of prescribing without seeing the patient; and mentioned special devices particularly, or merely in general, only to be considered partial to their makers or interested in their sale.

The power user who reads over what I have said, should find many places where he can set himself thinking with advantage to his pocket. That is why I prepared these "Hints."

THE END.

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